

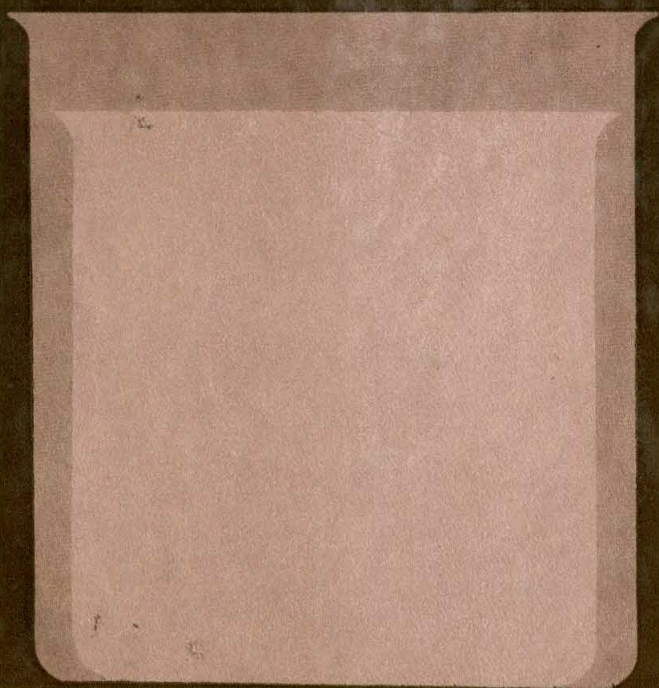
A.I. Busev and I.P. Efimov

CHEMISTRY

DEFINITIONS

NOTIONS

TERMINOLOGY



Mir Publishers Moscow

MENDELEEV'S PERIODIC TABLE

Periods	Rows	Groups of				
		I	II	III	IV	V
1	I	(H)				
2	II	Li 3 6.94 ₁ Lithium 2s ¹ 1/2	Be 4 9.01218 Beryllium 2s ² 2/2	5 10.81 Boron 2 2p ¹	6 12.011 Carbon 2 2p ²	7 14.0067 Nitrogen 5 2p ³
3	III	Na 11 22.98977 Sodium 3s ¹ 8/2	Mg 12 24.305 Magnesium 3s ² 8/2	13 26.98154 Aluminium 3 3p ¹ 8/2	14 28.0855 Silicon 4 3p ² 8/2	15 30.97376 Phosphorus 5 3p ³ 8/2
4	IV	K 19 39.0983 Potassium 4s ¹ 18/2	Ca 20 40.08 Calcium 4s ² 18/2	Sc 21 44.9559 Scandium 3d ¹ 4s ² 8/2	Ti 22 47.90 Titanium 3d ² 4s ² 10/8	V 23 50.9415 Vanadium 3d ³ 4s ² 8/2
	V	29 63.546 Copper 3d ¹⁰ 4s ¹ 18/2	30 65.38 Zinc 4s ² 2/2	31 69.72 Gallium 4p ¹ 18/8	32 72.59 Germanium 4p ² 18/2	33 74.9216 Arsenic 4p ³ 18/2
5	VI	Rb 37 85.4678 Rubidium 5s ¹ 18/8	Sr 38 87.62 Strontium 5s ² 18/2	Y 39 88.9059 Yttrium 4d ¹ 5s ² 18/2	Zr 40 91.22 Zirconium 4d ² 5s ² 18/8	Nb 41 92.9064 Niobium 4d ⁴ 5s ¹ 18/8
	VII	47 107.868 Silver 5s ¹ 18/8	48 112.41 Cadmium 5s ² 18/2	49 114.82 Indium 5p ¹ 18/8	50 118.69 Tin 5p ² 18/2	51 121.7 Antimony 5p ³ 18/8
6	VIII	Cs 55 132.9054 Cesium 6s ¹ 18/8	Ba 56 137.33 Barium 6s ² 18/2	La* 57 138.9055 Lanthanum 5d ¹ 6s ² 18/2	Hf 72 178.49 Hafnium 5d ² 6s ² 18/2	Ta 73 180.9479 Tantalum 5d ³ 6s ² 18/3
	IX	79 196.9665 Gold 5d ¹⁰ 6s ¹ 18/8	80 200.59 Mercury 6s ² 2/2	81 204.37 Thallium 6p ¹ 18/8	82 207.2 Lead 6p ² 18/2	83 208.980 Bismuth 6p ³ 18/2
7	X	Fr 87 [223] Francium 7s ¹ 18/8	Ra 88 226.0254 Radium 7s ² 18/8	Ac** 89 [227] Actinium 6d ¹ 7s ² 18/8	Ku 104 [261] Kurchatovium 6d ² 7s ² 18/8	

* LANTHANIDES

Ce 58 140.12 Cerium 4f ² 6s ² 8/2	Pr 59 140.9077 Praseodymium 4f ³ 6s ² 8/2	Nd 60 144.24 Neodymium 4f ⁴ 6s ² 8/2	Pm 61 [145] Promethium 4f ⁵ 6s ² 8/2	Sm 62 150.4 Samarium 4f ⁶ 6s ² 8/2	Eu 63 151.965 Europium 4f ⁷ 6s ² 8/2	Gd 64 157.2 Gadolinium 4f ⁷ 5d ¹ 6s ² 8/2
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** ACTINIDES

Th 90 232.0381 Thorium 6d ² 7s ² 8/2	Pa 91 231.0359 Protactinium 5f ² 6d ¹ 7s ² 8/2	U 92 238.029 Uranium 5f ³ 6d ¹ 7s ² 8/2	Np 93 237.0482 Neptunium 5f ⁴ 6d ¹ 7s ² 8/2	Pu 94 [244] Plutonium 5f ⁶ 7s ² 8/2	Am 95 [243] Americium 5f ⁷ 7s ² 8/2	Cm 96 [247] Curium 5f ⁷ 6d ¹ 7s ² 8/2
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OF THE ELEMENTS

VOSTOK
7, Camac Street
Calcutta-700017

elements

VI		VII		VIII	
✓		1 1s ¹ Hydrogen	H 1.0079	2 1s ² Helium	
8 6 2p ⁴ Oxygen	O 15.999 ₄	9 7 2p ⁵ Fluorine	F 18.998403	10 8 2p ⁶ Neon	
16 6 8 2 3p ⁴ Sulphur	S 32.06	17 7 8 2 3p ⁵ Chlorine	Cl 35.453	18 8 8 2 3p ⁶ Argon	
Cr 51.996 Chromium	24 1 13 8 3d ⁵ 4s ¹	Mn 54.9380 Manganese	25 2 13 8 3d ⁵ 4s ²	Fe 55.847 Iron	26 2 14 8 2 3d ⁶ 4s ²
		Co 58.9332 Cobalt	27 2 15 8 2 3d ⁷ 4s ²	Ni 58.70 Nickel	28 2 16 8 2 3d ⁸ 4s ²
34 6 18 8 2 4p ⁴ Selenium	Se 78.96	35 7 18 8 2 4p ⁵ Bromine	Br 79.904	36 8 18 8 2 4p ⁶ Krypton	
Mo 95.94 Molybdenum	42 1 13 8 2 4d ⁵ 5s ¹	Tc 98.9062 Technetium	43 2 13 8 2 4d ⁵ 5s ²	Ru 101.07 Ruthenium	44 1 15 8 2 4d ⁷ 5s ¹
		Rh 102.9055 Rhodium	45 1 16 8 2 4d ⁸ 5s ¹	Pd 106.4 Palladium	46 0 18 8 2 4d ¹⁰ 5s ⁰
52 6 18 18 8 2 5p ⁴ Tellurium	Te 127.6 ₀	53 7 18 18 8 2 5p ⁵ Iodine	I 126.9045	54 8 18 18 8 2 5p ⁶ Xenon	
W 183.8 ₅ Tungsten	74 2 12 32 8 2 5d ⁴ 6s ²	Re 186.207 Rhenium	75 2 13 32 8 2 5d ⁵ 6s ²	Os 190.2 Osmium	76 2 14 32 8 2 5d ⁶ 6s ²
		Ir 192.2 ₂ Iridium	77 2 15 32 8 2 5d ⁷ 6s ²	Pt 195.0 ₉ Platinum	78 1 17 32 8 2 5d ⁸ 6s ²
84 6 18 32 18 8 2 6p ⁴ Polonium	Po 209	85 7 18 32 18 8 2 6p ⁵ Astatine	At [210]	86 8 18 32 18 8 2 6p ⁶ Radon	Rn [222]

Tb 65 158.9254 Terbium	Dy 66 162.5 ₀ Dysprosium	Ho 67 164.9304 Holmium	Er 68 167.2 ₆ Erbium	Tm 69 168.9343 Thulium	Yb 70 173.0 ₄ Ytterbium	Lu 71 174.967 Lutetium
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Bk 97 [247] Berkelium	Cf 98 [251] Californium	Es 99 [254] Einsteinium	Fm 100 [257] Fermium	Md 101 [258] Mendelevium	(No) 102 [255] (Nobelium)	(Lr) 103 [256] (Lawrencium)
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CHEMISTRY.
DEFINITIONS, NOTIONS, TERMINOLOGY

А. И. Бусев и И. П. Ефимов

**ОПРЕДЕЛЕНИЯ,
ПОНЯТИЯ,
ТЕРМИНЫ
В ХИМИИ**

Издательство «Просвещение»
Москва

A.I. Busev and I.P. Efimov

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PREFACE

In studying chemistry and in reading popular scientific literature you sometimes come across passages whose meaning escapes you. This book is intended for secondary school students who wish to develop a deeper understanding of various chemical processes and natural phenomena. Here you will find accurate definitions and explanations of the most important terms used in general, inorganic, organic, analytical chemistry and in chemical engineering.

Most entries contain ethymologies which allow tracing the meaning of a term to its origin in ordinary language. Chemical compounds are as a rule given under their common names, with most important synonyms in parentheses. Names approved by the International Union of Chemistry are distinguished by the symbol (*).

To the memory of Professor Vadim N. Verkhovskii

A

abrasive [L *abradere*; *ab-*, away + *radere*, to scrape]. A natural or synthetic substance of high hardness used for wearing off or grinding objects to give them the desired size, shape, or finish. Abrasives often also have properties needed in the production of refractories and heating elements. Examples of naturally occurring abrasives are diamond, emery, quartz and its modifications, garnet, pumice. Synthetic abrasives include carborundum, abrasive aluminium oxide made by electric furnace fusion of materials high in **alumina**, boron carbide (see carbides), etc. Diamond is the hardest material of all natural and synthetic abrasives.

absorber [L *absorbere*; *ab-*, from + *sorbere*, to drink in]. An apparatus for the absorption of gases and for the separation of gas mixtures into the constituent parts by dissolving one or several components in a liquid called absorbent. An absorber is a column containing plates or other packing; a gas is fed in at its bottom part and removed at the top. A liquid is introduced at the top and removed at the bottom. Used in the chemical, petroleum, and other industries.

absorption of gases, see *absorber*. A taking up (dissolution) of substances by liquids or solids. Unlike adsorption, which is a surface phenomenon, absorption occurs in the bulk of the material that absorbs (absorbent). It may proceed as a mere dissolution but is often accompanied by chemical combination (chemisorption). The process is used to separate gas mixtures, purify gases, in the production of various compounds such as sulphuric acid (absorption of SO_3), hydrochloric acid (absorption of gaseous HCl). It is also employed in the analytical and radiochemistry for separating mixtures of elements and isolating pure radioactive elements.

acaricide [Gk *akari*, a mite + *L caedere*, to kill]. Any substance used to kill mite pests which live as parasites upon animals or plants, or in prepared foods, e.g. sulphur, various organic compounds containing sulphur, chlorine, and phosphorus.

acceptor [L *ad*, to + *capere*, to take].

1. An atom or an ion, or a group of atoms which accepts electrons and forms a chemical bond using its own free orbital and a lone electron pair of a donor.

2. An imperfection in a semiconductor which causes hole conductivity.

acetaldehyde (ethanal*; acetic aldehyde; aldehyde) CH_3CHO .

Properties: colourless liquid; pungent odour; miscible with water, alcohol, and ether, b.p. 28°C . Reactions are typical for aldehydes.

Derivation: hydration of acetylene in the presence of mercuric salts as catalyst (Kucherov's reaction); oxidation of ethyl alcohol.

Uses: the production of acetic acid, butadiene, aldehyde polymers; organic synthesis.

acetamide (ethanamide*, acetic acid amine) CH_3CONH_2 .

Uses: organic synthesis (solvent); hygroscopic agent; the manufacture of paper and leather.

acetate, a compound derived from acetic acid by replacing the acid hydrogen by a metal or an organic radical.

1. Metal acetates are salts soluble in water, e.g. sodium acetate, CH_3COONa . Prepared by the dissolution of metal oxides, hydroxides, or certain salts such as metal carbonates in acetic acid.

2. Organic acetates are esters of acetic acid.

acetic acid (ethanoic acid*) CH_3COOH .

Properties: Colourless liquid; pungent odour; soluble in water. Pure compound called glacial acetic acid is a solid resembling ice and existing at temperatures below $+16.5^\circ\text{C}$. Dilute acetic acid is called vinegar acid. A weak acid.

Occurrence: in plants as free acid and in the form of acetates.

Derivation: by the oxidation of acetaldehyde made from acetylene by Kucherov's reaction.

Uses: widely applied in the chemical industry, e.g. in the manufacture of acetone, cellulose acetate, organic solvents (amyl acetate), pharmaceuticals (aspirin), lac-

quers, dyes. Has varied applications in the analytical chemistry, in the production of foods and in housekeeping (vinegar), in medicine. Metal acetates also have practical applications.

acetone (2-propanone*, dimethyl ketone) $\text{CH}_3-\text{C}-\text{CH}_3$. The



simplest ketone.

Properties: colourless liquid; characteristic odour; flammable. Miscible with water and organic solvents.

Uses: solvent for many organic products such as cellulose acetate and cellulose nitrate, fats, wax, and rubber; also dissolves a number of metal salts, e.g. calcium chloride and potassium iodide; a starting material for the synthesis of various organic compounds; the production of synthetic silk, smokeless gunpowder, and pharmaceuticals.

acetylacetone (2,4-pentanedione*) $\text{CH}_3\text{COCH}_2\text{COCH}_3$.

Properties: forms stable complexes with metal ions.

Uses: in the analytical chemistry for the determination and isolation of Be, Cu, Cr, Fe, and other metals; in the radiochemistry for the isolation of radioactive isotopes; in the organic synthesis.

acetyl cellulose. Cellulose acetates.

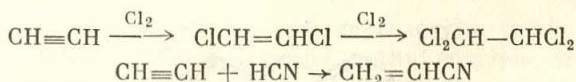
Derivation: by the action of acetic anhydride on cellulose, from cotton or wood cellulose as raw materials.

Properties: stable in the light, not flammable, good physicochemical characteristics.

Uses: the production of photofilm, acetate fiber, plastics, lacquers, etc.

acetylene (ethyne*) $\text{CH}\equiv\text{CH}$. The simplest alkyne, discovered in 1836 by Davy. In 1862, synthesized from carbon and hydrogen by M. Berthelot.

Properties: colourless gas, slightly soluble in water, lighter than air, contained in illuminating gas. Mixtures with air are explosive. Typical reactions are addition reactions proceeding with the break of one or two π -bonds:



Reacts with water in the presence of mercury salts and other catalysts to give acetic aldehyde (Kucherov's reac-

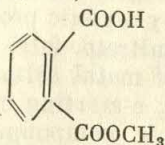
tion). Can polymerize to benzene and other organic compounds.

Derivation: in industry, by the action of water on calcium carbide (Wöhler, 1862) and by cracking of methane.

Uses: welding (on account of high flame temperature); the production of acetic acid, ethanol, solvents, plastics, rubber, aromatic hydrocarbons.

acetylene series (alkynes) C_nH_{2n-2} . Unsaturated open-chain hydrocarbons with one triple bond between carbon atoms.

acetylsalicylic acid (aspirin)



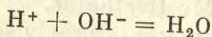
Used in medicine as an antipyretic and analgesic.

acids. Electrolytes that liberate hydrogen ions in solution.

Acids may contain oxygen (H_2SO_4 , H_2CO_3 , etc.) or be free of it (HCl , H_2S , etc.). The former are formed in the interaction of some acidic oxides with water, and the latter in the interaction of certain elements with hydrogen. The number of hydrogen atoms in an acid molecule as a rule determines its basicity. For example, HCl and HNO_3 are monobasic, H_2SO_4 and H_2CrO_4 dibasic, and H_3PO_4 is a tribasic acid. Many acids are very soluble in water; solutions of acids have a sour taste and change the colour of indicators. Acids react with metals, basic oxides, bases, and salts.

acidic oxides. See *oxides*.

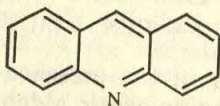
acidimetry and alkalimetry. The most important titrimetric methods for the determination of acids and bases according to the neutralization reaction



The titration by a solution of a base is called alkalimetry; acidimetry is the titration by a solution of an acid.

acrichine (acriquine). See *mepacrine*.

acridine



Properties: colourless crystals, m.p. 111 °C. A weak base, chemically stable.

Derivation: from coal tar.

Uses: the synthesis of dyes and pharmaceuticals.

Acrilan. Trademark for synthetic fibre made from acrylonitrile. Used in the manufacture of knitted fabrics, suitings, fabrics for technical uses.

acrolein. See *acrylaldehyde*.

acrylaldehyde (propenal*, acrolein, acrylic aldehyde)
 $\text{CH}_2=\text{CH}-\text{CHO}$.

Properties: a colourless inflammable liquid with an irritating smell; volatile, b.p. 52.5 °C, very soluble in ethanol and other organic solvents. Olefinic aldehyde; gives acrylic acid under the action of air oxygen; readily polymerizes.

Derivation: by heating glycerin in the presence of dehydrating agents. Formed in heating fats, oils.

Uses: the production of plastics, synthetic resins; the organic synthesis, e.g. the preparation of glycerin. Irritating to mucous membrane.

acrylamide (propenamide*) $\text{CH}_2=\text{CHCONH}_2$.

Properties: colourless crystals, soluble in water, methanol, ethanol, and acetone.

Derivation: hydrolysis of acrylonitrile.

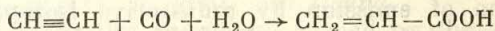
Uses: polymers based on acrylamide are important products.

acrylate $\text{CH}_2=\text{CHCOOR}$ where R is an alkyl radical such as CH_3 , C_2H_5 , an ester of acrylic acid. Easy to polymerize. Used in the production of polymers. See *polyacrylates*.

acrylic acid $\text{CH}_2=\text{CH}-\text{COOH}$. The simplest monobasic olefinic acid.

Properties: colourless liquid with acrid odour, soluble in water, b.p. 141 °C. Easily polymerizes to give polyacrylic acid (see *polyacrylates*).

Derivation: from acetylene, carbon monoxide, and water:



Uses: esters of acrylic and methacrylic acids, especially methyl methacrylate and methyl acrylate, are widely used in the production of plastics. See *methacrylates*.

acrylonitrile (propenenitrile*, vinyl cyanide) $\text{CH}_2=\text{CHCN}$.

Properties: colourless mobile liquid with peculiar odour,

b.p. 77 °C. Mixtures with air containing 3 to 17 per cent acrylonitrile are explosive. Poisonous.

Uses: the manufacture of certain kinds of synthetic rubber; synthetic fiber Nitron is made by polymerizing acrylonitrile.

actinides (actinoids, actinons) [Gk *aktis*, *aktinos*, ray + *eidos*, a form, shape]. The 5f family of elements standing beyond actinium in the 7th period of the Mendeleev Periodic Table of Elements with the atomic numbers 90 to 103. All actinides are radioactive. The ^{233}U , ^{235}U , and ^{239}Pu isotopes are used as nuclear fuel. The first three actinides, i.e. thorium, protactinium, and uranium, occur in nature; the heavier actinides, the transuranic elements, were synthesized in nuclear reactions. For properties see entries on particular actinides.

actinium [Gk *aktis*, *aktinos*, ray] Ac. A radioactive Group III element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 89. The most stable isotope is ^{227}Ac , half-life, $T_{1/2}$, 22 years, emits β -particles (98%) and α -particles (1.2%). Discovered by A. Debierne in pitchblende waste in 1899 (one ton of pure pitchblende contains 0.15 mg of actinium). Obtained by neutron bombardment of radium. A silvery white metal, valence +3, the chemical properties of actinium resemble those of lanthanum. A dangerous radioactive poison.

actinoids. See *actinides*.

actinon An. One of the radon isotopes, ^{219}Rn , half-life, $T_{1/2}$, 3.92 days. Discovered in 1902.

activated carbon (active charcoal). A porous adsorbent with a well developed internal surface. Made by strong heating of charcoal in a stream of water vapour. Used to separate mixtures of gases, hydrocarbons, to purify solutions (to remove organic contaminants), in medicine, in gas masks.

activation analysis. An analytical technique based on the detection of emission by radioactive isotopes formed when the substance is bombarded by high energy nuclear particles. A very sensitive method applied to determine impurities in metals, alloys, semiconductors, etc.

activation energy. The lowest energy of reacting particles needed for the reaction event to occur.

activation of molecules. In chemical kinetics the transition

of a molecule from an inactive state to a state with increased energy sufficient for a chemical reaction to occur.

activators [*L. actus*, a doing or moving]. In chemistry: (i) substances (promoters) added to catalysts to increase their activity, selectivity, or stability. For example, iron used to catalyze the synthesis of ammonia contains several per cent Al_2O_3 and K_2O . Vanadium (V) oxide which catalyzes oxidation of SO_2 to SO_3 is activated by adding alkali metal oxides; (ii) atoms of elements introduced in small amounts in phosphor crystal lattices which, together with their host lattice environment, form luminescence centers. Zinc sulfide phosphor crystals are activated by Cu, Ag, Au, Mn, and rare earth elements; rare earth elements are used to activate fluorite, CaF_2 ; (iii) substances promoting corrosion such as hydrogen ions, oxygen dissolved in water; (iv) substances that amplify the action of enzymes.

activity (of ions). An effective (apparent) concentration of ions depending on interionic interactions in solution. Activity differs somewhat from the total concentration. The ratio of activity (a) to the total concentration of a substance in solution (c , mole/litre), that is the activity of ions at a 1 mole/litre concentration, is called the activity coefficient:

$$\gamma = a/c$$

activity of metals. See *electromotive series*.

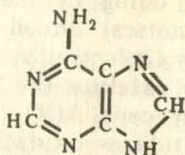
acyclic compounds (aliphatic compounds). Organic compounds with open chains where all carbon atoms are linked with each other to form simple or branched structures. Two major classes of aliphatic compounds are saturated hydrocarbons containing only single bonds between carbon atoms such as methane homologues and unsaturated hydrocarbons also containing double and triple C—C bonds such as ethylene and acetylene series.

addend [*L. addere*, to add]. See *ligand*.

adduct. A molecular compound formed by the addition of molecules to each other. The term usually refers to species comprising moieties with saturated valences. Adducts are mostly prepared by mixing the reagents. Employed for industrial extraction of certain hydrocarbons from their mixtures. Also applied in the analyt-

ical chemistry, radiochemistry, and chemical technology to separate and identify various elements.

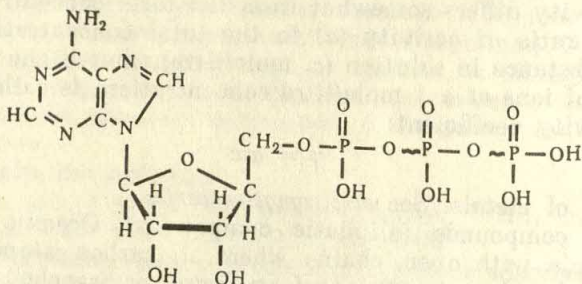
adenine (6-aminopurine)



An aminoderivative of purine. Found in nucleic acids. Properties: colourless crystals; soluble in acids and alkalis, insoluble in ether and chloroform.

Derivation: by acidic hydrolysis of nucleic acids.

adenosine triphosphate (adenyltriphosphoric acid, ATP). The most important nucleotide for the transfer and storage of energy in vivo, especially in reactions associated with muscular activity. Energy is stored in phosphate bonds with which ATP participates in metabolism (bonds especially rich in energy are labelled ~)



The ATP molecule] easily loses two phosphate groups to release 40 to 50 kJ/mole. Transformations of ATP occur under the action of enzymes. Found in tissue of animals and plants. Classified as nucleotide.

adhesion [L *adhaerere*; ad-, to + *haerere*, to stick].

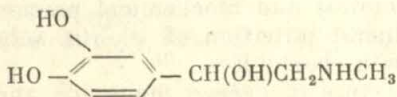
Arising of forces between two different bodies, solids or liquids, brought into contact. A particular case is cohesion which is adhesion of two like bodies. Adhesion is caused by the van der Waals (intermolecular) forces, formation of metallic or ionic linkages. Adhesion of solids and polymers is the most typical example (glueing of materials, coatings).

adipic acid (hexanedioic acid*) $\text{HOOC}(\text{CH}_2)_4\text{COOH}$. A dibasic carboxylic acid.

Properties: colourless crystals, m.p. 149-150 °C.

Uses: an important material for the production of nylon fiber; esters of adipic acid are employed as plasticizers and lubricants.

adrenaline (epinephrine; 3,4-dihydroxy- α -(methylaminoethyl) benzyl alcohol). A hormone of the adrenal glands.



Increases arterial pressure because of constricting action on peripheral blood vessels, participates in carbohydrate metabolism.

adsorbent. See *adsorption*. A solid or a liquid at whose surface adsorption occurs. Typical adsorbents are silica gel, activated carbon, some oxides, resins, etc.

adsorption [L *ad-*, to + *sorbere*, to drink in, suck]. The concentration of gases or dissolved substances on the surface of a solid or a liquid; used to separate mixtures of various gases or liquids, to dry and purify gases as in gas masks and liquids by passing them through activated carbon, to purify water. Employed in the chemical, petroleum, polygraphic, sugar industries, in the production of dyes and lacquers, etc. Plays an important part in processes in vivo such as consumption of substances by cells, enzymatic reactions and in processes occurring in soil.

agar-agar [Malay, *seaweed*]. A product made from some kinds of seaweed. Mainly contains carbohydrates. Solutions of agar-agar in hot water form gelation on cooling. Used in chemistry, microbiology for the preparation of solid nutrients, medicine, in the production of marmalade, etc.

agate [Gk *Achates*, Sicilian river]. A mineral, a variety of chalcedony. Hardness 7. Colour grey, white, and red. Chemically stable, resistant to abrasion. Classified as a semiprecious stone. Used in the manufacture of precision instruments, pestles and mortars for analytic work, pivot supports for balances, watch stones, in ornaments.

agglomeration [L *agglomerare*, ad-, to + *glomerare*, to form into a ball]. The formation of comparatively large

porous bodies (agglomerates) from small ore particles or from powder by sintering. The lower melting constituents make solid particles stick together upon cooling. Employed in the calcination of iron and lead ores, zinc concentrates, etc.

agricultural chemistry [Gk *agros*, country]. The science of plant nutrition and of using fertilizers and chemical means of protecting plants to increase the yield of crops. Studies chemical and biochemical processes in soil and plants, mineral nutrition of plants, substances stimulating growth, herbicides.

air gas. A mixture of carbon monoxide and air nitrogen, made by blowing air through incandescent coal. Burning of coal gives CO_2 which undergoes reduction by incandescent coal to carbon monoxide, CO ($\text{CO}_2 + \text{C} = 2\text{CO}$). Used as a fuel in metallurgy, in glass and ceramics manufacture, for internal combustion engines.

alabaster [Gk *alabastros*, from name of Egypt town]. $2\text{CaSO}_4 \cdot \text{H}_2\text{O}$. The product of calcination of gypsum, a cement. Obtained by heating gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, to 150-170 °C. Quickly solidifies when mixed with water to produce gypsum. Used as a bonding material in building, in medicine.

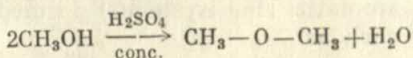
α -alanine (α -aminopropionic acid, 2-aminopropanoic acid*) $\text{CH}_3\text{—CH}(\text{NH}_2)\text{—COOH}$. An aminoacid contained in most proteins. Synthesized in animals and man.

albumens (albumins) [L *albumen*, white of egg]. The simplest natural proteins, soluble in water. Occur in egg-white, blood serum, milk, and seeds of plants. Uses: pharmaceutical, confectionary, textile, and other industries.

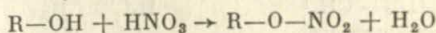
alchemy [Ar *al-kimiya*]. The chemistry of the Middle Ages. Alchemists sought philosophers' stone believed to change base metals into gold. That search, however, promoted the developments of experimental techniques and the synthesis of new substances.

alcohol. An organic substance containing the hydroxyl group attached to a hydrocarbon radical. Depending on the number of hydroxyl functions alcohols are called monohydric (CH_3OH , methanol; $\text{C}_6\text{H}_5\text{CH}_2\text{OH}$, benzyl alcohol), dihydric ($\text{CH}_2\text{OH—CH}_2\text{OH}$, glycol), polyhydric ($\text{CH}_2\text{OH—CH}(\text{OH})\text{—CH}_2\text{OH}$, glycerol). Alcohols containing aromatic radicals are classified as phenols.

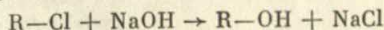
Properties: the lower saturated alcohols are mobile liquids with a characteristic odour and a burning taste, soluble in water; alcohols with longer chains (C_4 to C_{11}) are oily liquids not miscible with water; C_{12} and the higher alcohols are solids, odourless and tasteless. React with active metals to give metal alkoxides such as CH_3ONa ; primary alcohols are oxidized to aldehydes and secondary ones to ketones; can be dehydrated:



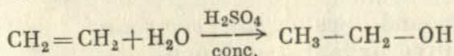
form esters:



Derivation: by the action of alkalis on halogenated hydrocarbons:

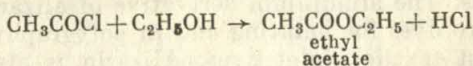


or the hydration of olefins:



Alcohols are formed in fermentation of carbohydrates. Uses: widely applied in the organic synthesis, as solvents, in the production of pharmaceuticals, cosmetics, explosives, synthetic fiber, plastics, in medicine, and food industry.

alcoholysis. An exchange decomposition reaction under the action of alcohols, for example the interaction of acetyl chloride with ethanol:



aldehyde. An organic compound containing the group $-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}.$

Properties: the first member of the series, formaldehyde

$H-\overset{\text{O}}{\underset{\text{H}}{\text{C}}}$, is a gas, the following members are liquids and

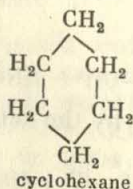
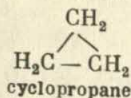
the higher aldehydes are solids. Solubility in water decreases as the molecular weight increases; the higher aldehydes are insoluble. Aldehydes are reactive substances; they can easily be oxidized, e.g. by an ammonia

solution of Ag_2O (the reaction of silver mirror), to give the corresponding acids. Participate in polymerization and condensation reactions.

Derivation: by oxidizing alcohols.

Uses: the manufacture of formaldehyde resins (plastics), perfumes (vanillin is an aromatic aldehyde), the synthesis of acetic acid, methenamine, and other substances.

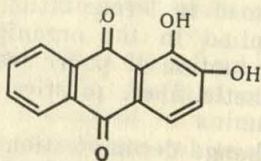
alicyclic compound. An organic compound incorporating cyclic not aromatic ring system(s) formed by carbon atoms only such as



Alicyclic and aromatic compounds are classified as carbocyclic compounds.

aliphatic compound. See *acyclic compound*.

alizarin (1,2-dihydroxyanthraquinone)



An important starting material for the synthesis of complex dyes. The aluminium derivative of alizarin is used to prepare dyes for painting and in polygraphy, alizarin gives fast textile violet dyes. Alizarin is also applied in the analytical chemistry to identify aluminium ions and ions of certain other elements.

alkali [Ar *al-qaliy*, *al*, the + *qaliy*, ashes of saltwort]. A base highly soluble in water to produce OH^- ions in a large concentration. Group IA and IIA metal hydroxides except for $\text{Be}(\text{OH})_2$ and $\text{Mg}(\text{OH})_2$ are classified as alkalis. Alkali metal hydroxides such as LiOH , NaOH , and KOH are the strongest bases known as caustic alkalis. Alkali earth metal hydroxides, i.e. $\text{Ca}(\text{OH})_2$, $\text{Sr}(\text{OH})_2$, $\text{Ba}(\text{OH})_2$, and $\text{Ra}(\text{OH})_2$, are weaker bases. Alkalis are white hygroscopic solids. Their dissolution is accom-

panied by the evolution of much heat. Solutions of alkalis turn litmus blue and phenolphthalein deep purple-red. Alkalis eat living tissue, especially of animal origin. Widely applied in various industries. See *sodium hydroxide*, *potassium hydroxide*.

alkalimetry. See *acidimetry* and *alkalimetry*.

alkaloid [alkali + Gk *eidos*, a form, shape]. A basic nitrogenous organic compound, usually of vegetable origin. Most alkaloids have complex structures incorporating heteroatomic rings. Alkaloids as a rule have a strong action on organisms.

Derivation: from plants, especially from buttercups, poppies, and leguminous plants.

Uses: medicine.

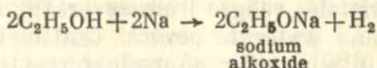
alkali metals. Group IA elements including lithium, sodium, potassium, rubidium, cesium, and radioactive francium. Called alkali metals because their hydroxides, MeOH, are the strongest bases known (alkalis). Alkali metals are chemically active elements; their reactivity increases in passing from lithium to francium.

alkaline earth metals. Group IIA elements (calcium, strontium, barium, and radioactive radium) whose oxides (called earths by alchemists) make water alkaline, whence their name; reactive.

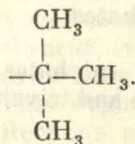
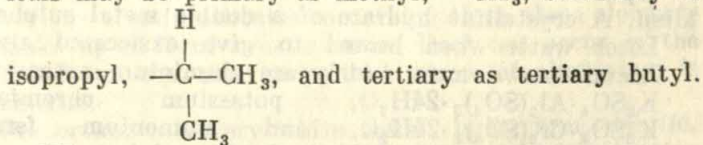
alkane (paraffin). See *saturated hydrocarbon*.

alkene. See *unsaturated hydrocarbon*.

alkoxide. Metal alkoxides are products of the interaction between alcohols and alkali metals:



alkyl. A univalent radical of the alkane series. Alkyl radicals may be primary as methyl, $-\text{CH}_3$, secondary as



alkylation. The introduction of an alkyl group into an organic substance molecule.

alkyne (alkine). See *unsaturated hydrocarbons*.

allotropy [Gk *allos*, other + *tropos*, way, manner]. The existence of a chemical element in the form of two or several simple substances (allotropic forms) differing in their structure and shape. For example, carbon exists as diamond and graphite. Sulphur, selenium, phosphorus, tin, iron, etc. also form several simple substances each. Allotropy is either the result of crystal structure variations (allotropy of form) or arises because of combination of different numbers of atoms into molecules of simple compounds (allotropy of composition, e.g. oxygen, O_2 , and ozone, O_3).

alloy. A composition of two or more metals; can also contain some non-metallic elements such as carbon. Alloys show properties typical for metals. Usually obtained by crystallizing melts, by sintering (powder metallurgy), etc. May be heterogeneous mixtures or chemical compounds and solid solutions with homogeneous structures. Metal alloys such as bronze and steel have wide applications.

alpha particle. Helium nucleus, ${}^4_2\text{He}$, a combination of two protons and two neutrons, positively charged (+2). The mass number is four. Emitted by radioactive isotopes of various elements (${}^{226}\text{Ra}$, ${}^{222}\text{Rn}$, ${}^{210}\text{Po}$, ${}^{238}\text{U}$, etc.). Alpha particles have a strong ionizing action on the medium and quickly lose their energy. The free path of alpha particles ranges from several dozens of microns in metals and water to several centimeters in the air. Employed in a number of nuclear reactions to produce neutrons, ${}_4^9\text{Be} + {}_2^4\text{He} \rightarrow {}_0^1n + {}_6^{12}\text{C}$, and radioactive isotopes of certain elements.

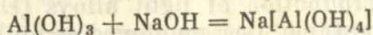
alum. A crystalline hydrate of a double metal sulphate. Loses water when heated to give exsiccated alum. Alums known most widely are aluminium potassium, $\text{K}_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, potassium chromium, $\text{K}_2\text{SO}_4 \cdot \text{Cr}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, and ammonium ferric, $(\text{NH}_4)_2\text{SO}_4 \cdot \text{Fe}_2(\text{SO}_4)_3 \cdot 24\text{H}_2\text{O}$, double sulphates. Properties: soluble in water.

Derivation: by mixing hot solutions of sulphates of univalent (Na^+ , K^+ , Rb^+ , Cs^+ , NH_4^+ , Tl^+) and trivalent (Al^{3+} , Cr^{3+} , Fe^{3+} , etc.) metals.

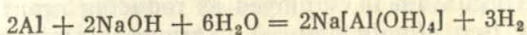
Uses: tanning agents in the manufacture of leather, as mordants in dyeing, the production of paper, photography, medicine.

alumina. See *aluminium oxide*.

aluminates of metals. Metal salts formed in the interaction of alkali with freshly precipitated aluminium hydroxide:



Also formed in the dissolution of aluminium metal or Al_2O_3 in alkalis:



The $[\text{Al(OH)}_4]^-$ ion occurs in aqueous solutions. Alkali metal aluminates are very soluble in water; because of hydrolysis their aqueous solutions are only stable in the presence of excess alkali. Fusing together of Al_2O_3 and metal oxides yields anhydrous metal aluminates that can be regarded as derivatives of metaaluminic acid, HAlO_2 . For example, calcium metaaluminate, $\text{Ca(AlO}_2\text{)}_2$, can be prepared by fusing together Al_2O_3 and CaO . Naturally occurring metal aluminates are magnesium and calcium aluminates (MgAl_2O_4 , CaAl_2O_4), chrysoberyl (beryllium aluminate, BeAl_2O_4). Sodium aluminate is formed as an intermediate in the production of Al_2O_3 ; it is used in the textile and paper industries, for the purification of water. Calcium aluminate is the major component of quickly solidifying alumina cement.

aluminium [L *alumen*, *aluminis*, *alum*]. A Group III element of the third period of the Mendeleev Periodic Table of elements, atomic number 13, atomic mass 26.9815, one stable isotope, ^{27}Al (100%). Aluminium metal was obtained by Wöhler in 1827. Third to oxygen and silicon, in abundance in earth's crust (8.8%); various aluminosilicates containing these three elements make up 82% of crust's mass. Does not occur in the free form: the most important source of aluminium is bauxite.

Properties: a silvery white metal, light, firm, ductile, a good conductor of heat and electricity. A highly reactive element, valence +3. Combines with oxygen and is covered by an oxide film, Al_2O_3 , when stored in the air. This explains high corrosion resistance of aluminium. Remains unattacked under the action of conc. HNO_3 .

Readily dissolves in alkalis, dilute HCl and H_2SO_4 . Like Al_2O_3 aluminium hydroxide is amphoteric: in aqueous solutions, it reacts with acids to give a hydrated ion, $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$, and with alkalis to give metal aluminates. Derivation: by the electrolysis of aluminium oxide made from bauxite and dissolved in molten cryolite, Na_3AlF_6 . Uses: the production of light alloys (Dural, Silumin) for aircraft, automobiles; employed as building material, as material for chemical equipment, in the manufacture of electric wire, capacitors, in building of nuclear reactors. Aluminium is employed as reducing agent in metallurgy (see *aluminothermy*). Various aluminium compounds have practical applications. Aluminium oxide, aluminium chloride, AlCl_3 , and hydrated aluminium chloride, $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$, are used as catalysts in the organic synthesis, aluminium sulphate, $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$, and potassium alum, $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, as mordants in dyeing, for tanning leather, in the manufacture of paper, and in the purification of water. Silver paint used in building and architecture for protecting from corrosion and for decorative purposes in a mixture of aluminium powder and mineral oil. Organoaluminium compounds are employed as starting materials for the synthesis of other organometallics; alkylaluminium derivatives are catalysts of the polymerization of olefines.

aluminium oxide (alumina) Al_2O_3 . A compound of oxygen and aluminium, a constituent of clays.

Properties: m.p. 2050°C , insoluble in water, amphoteric.

Occurrence: clays, corundum (colourless), ruby (red), sapphire (blue).

Derivation: by heating aluminium hydroxide and its salts to high temperatures (1200°C); from aluminothermic reactions. The major sources are bauxite, nephelines, kaolins, etc.

Uses: the production of aluminium, catalysis, chromatography (separation of various substances). Also employed as an abrasive (see *corundum*) and a refractory.

aluminosilicates. Silicates containing aluminium; compounds most abundant in earth's crust. Examples are feldspars and mica. In nature, undergo gradual disintegration (erode) to give kaolin as the major product. Kaolin is used in the production of porcelain. Hydrated aluminosilicates, natural (zeolites) and synthetic (permu-

tites), are employed as ion exchangers, e.g. in the purification of water.

aluminothermy. A process for the preparation of metals, non-metals, and alloys in which aluminium reduces another element from its oxide:



The reaction was discovered in 1859 by Beketov. It releases a large amount of heat. Employed to obtain chromium, vanadium, manganese, tungsten, and other metals and alloys. Thermit, a mixture of aluminium powder with iron oxide, is used in welding rails, steel tubes, metallic structures.

alunite (alum stone) $[\text{Fr}] \text{KAl}_3[\text{SO}_4(\text{OH})_2]_3$. A mineral of white or grey colour.

Uses: the production of alum, potassium compounds, alumina.

amalgam $[\text{Fr } \textit{amalgame}]$. A liquid or solid alloy formed in the dissolution of a metal in mercury. Alkali and alkaline earth metals and certain other elements give stable compounds with mercury. When copper, silver, gold, etc. amalgams are heated mercury is distilled off. Iron does not give amalgams, and mercury can be transported in iron vessels.

Uses: gilding of metals, the manufacture of mirrors. Alkali metal and zinc amalgams are employed as reducing agents. Amalgam are used in the electrolytic isolation of rare metals, in the extraction of some metals from their ores (see *amalgamation*).

amalgamation. A process for extracting metals from their ores by dissolving them in mercury. The amalgamated particles are separated from the rest of the ore, and mercury is distilled off. Used to extract gold, silver, platinum, and other metals from ores and concentrates.

amber. A fossil resin of a pine of the Tertiary Period, an amorphous substance.

ambergris. A waxy material of a complex composition with a fine peculiar odour. Formed in intestines of the sperm whale. Used in perfumery.

americium Am. A radioactive element of the actinide series, atomic number 95. Synthesized in 1944. The longest lived isotopes are ^{243}Am (half-life, $T_{1/2}$, of about 8000 years) and ^{241}Am ($T_{1/2} = 458$ years). A silvery soft

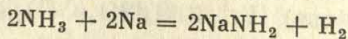
metal, forms compounds in the oxidation states +3, +4, +5, and +6.

amethyst [Gk *amethystos*, not drunken (believed to prevent intoxication)]. A transparent violet variety of quartz, a semiprecious stone.

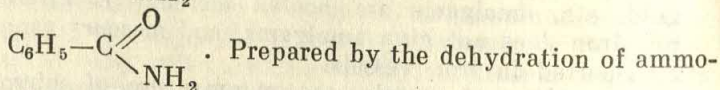
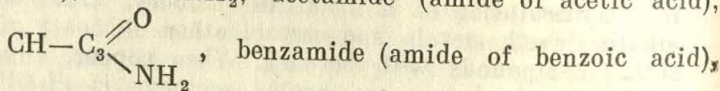
Uses: gem stone.

amide fertilizers. Nitrogen fertilizers containing nitrogen in the form of amides such as urea (carbamide), calcium cyanamide, urea-formaldehyde fertilizers.

amides of metals MeNH_2 are formed in the interaction of active metals with ammonia. For example, sodium amide, NaNH_2 , is prepared by passing a flow of ammonia gas over molten sodium:



amides of organic acids. Carboxylic acid derivatives in which the hydroxyl group is replaced with the amino group, NH_2 , such as formamide (amide of formic acid), $\text{H}-\text{CONH}_2$, acetamide (amide of acetic acid),



nium salts of carboxylic acids. All amides except for formamide are crystalline solids, slightly soluble in water, soluble in ethanol and other organic solvents. Give neutral aqueous solutions. When heated in the presence of acids or bases undergo hydrolysis to yield the corresponding acids and ammonia.

Uses: solvents; the synthesis of sulphanilamides; the production of polymers (polyamides).

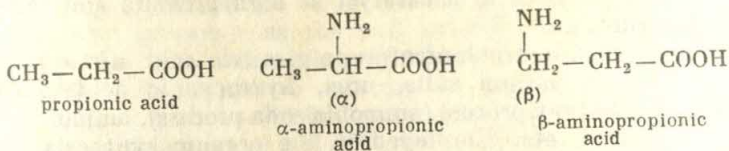
amination. The introduction of the amino group, $-\text{NH}_2$, or a substituted amino group, $-\text{NHR}$ or $-\text{NR}_2$, where R is an organic radical, into molecules of various organic substances, e.g. under the action of alkali metal amides, or by treating a halogenated organic compound with ammonia.

amines. Ammonia derivatives with one or more hydrogen atoms replaced by organic radicals such as methylamine, CH_3NH_2 , dimethylamine, $(\text{CH}_3)_2\text{NH}$, aniline (phenylamine), $\text{C}_6\text{H}_5\text{NH}_2$. Frequently occur in nature.

Derivation: amines of the fatty series are prepared by treating alcohols with ammonia; aromatic amines are obtained through the reduction of the corresponding nitrocompounds.

Uses: the production of dyes, pharmaceuticals (sulphanilamides), high-molecular-weight compounds, etc.

amino acids. Carboxylic acids containing one or several amino groups, very common in nature, occur in proteins. Are classified as α -, β -, or γ -amino acids depending on the position of the amino group relative to the carboxyl function



Proteins contain α -amino acids. Amino acids also differ from each other in the number of carboxylic groups (mono- and dicarboxylic amino acids) and in the number of amino-substituents (mono- and diamino acids).

Properties: crystalline solids. Many amino acids are soluble in water and insoluble in organic solvents, have sweetish taste. Give a neutral reaction in aqueous solutions.

Derivation: more than 20 α -amino acids were isolated from the hydrolysis of protein substances; synthesized by treating halogenated acids with ammonia. In organisms, amino acids serve as starting materials for the synthesis of proteins of various organs and tissue, hormones, enzymes, and other essential components. In industry, α -amino acids are used in the production of synthetic fiber.

amino group $-\text{NH}_2$. Compounds containing the amino group as a rule have basic properties.

ammonal. See *ammonia*, *ammonite*.

ammonia NH_3 .

Properties: a colourless gas with a characteristic pungent odour, almost two times lighter than air, easily liquefied (b.p. -33.4°C), very soluble in water: 1 volume unit of H_2O dissolves 700 volume units of NH_3 at 20°C . Aqueous solutions of NH_3 are called ammonia water

or ammonia spirit. Reacts with acids to give the corresponding ammonium salts, forms complex compounds with some metal salts, interacts with alkali and alkaline earth metals to give metal nitrides or metal amides depending on the conditions. Catalytic oxidation of ammonia to nitrogen oxides is the basic process in one of the methods of the synthesis of nitric acid.

Derivation: in nature, ammonia is formed in the decomposition (putrefaction) of nitrogenous organic substances. The major industrial process for the production of ammonia is its synthesis from hydrogen and air nitrogen in the presence of a catalyst at high pressure and temperature.

Uses: chemical manufacture, e.g. nitric acid, nitric acid salts, ammonium salts, urea, hydrocyanic acid, soda by the Solvay process (ammonia soda process), ammonium fertilizers, etc. Employed in the organic synthesis, as a refrigerative agent, for nitriding steel, in medicine (ammonia spirit).

ammonia, liquid (anhydrous).

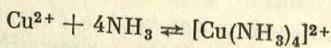
Properties: a colourless mobile liquid with a characteristic odour, contains 82.2% N, density 0.6 at 20 °C.

Derivation: by liquefying ammonia gas; transported in gas cylinders under pressure.

Uses: a solvent, e.g. for alkali and alkaline earth metals which form blue solutions with metallic glitter and high electric conductivity. These solutions slowly decompose to evolve hydrogen and give amides. Liquid ammonia and its aqueous solutions are employed as liquid fertilizers, and for the ammonization of superphosphate.

ammonia complexes. Products formed in the interaction of metal salts with ammonia.

Derivation: reactions of salt solutions with aqueous ammonia; treatment of solid salts with gaseous or liquid ammonia. For instance, copper ammonia complex is formed in the reaction



Ammonia complexes have different compositions, e.g. $[\text{Ag}(\text{NH}_3)_2]^+$, $[\text{Ni}(\text{NH}_3)_6]^{2+}$, and stabilities in aqueous solutions.

Uses: in the analytical chemistry for the identification and separation of metal ions.

ammonia water (aqua ammoniac). Aqueous solution of ammonia.

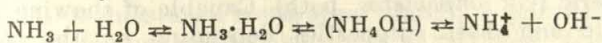
Derivation: by saturating water with synthetic gaseous ammonia (the concentration of ammonia can amount to 25%, density 0.9) or with ammonia formed in coking bituminous coal in coke ovens.

Uses: the preparation of ammonium salts (nitrogen fertilizers), the production of soda, dyes, etc.

ammonification. The decomposition of nitrogenous organic substances under the action of various bacteria in soil to give ammonia as the end product. The process is essential for maintaining fertility of soil.

ammonite. An explosive mixture of ammonium nitrate, NH_4NO_3 , with a solid fuel or an explosive material. Ammonals (mixtures of NH_4NO_3 and aluminium metal powder) also belong here.

ammonium NH_4^+ . An inorganic radical, does not exist in the free state. Plays the part of a univalent metal in salts. The dissolution of ammonia in water is accompanied by the reaction:



See also *ammonium salts*.

ammonium fertilizers. Fertilizers containing nitrogen in the form of ammonium compounds such as ammonium nitrate, NH_4NO_3 , ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$, ammonium chloride, NH_4Cl , ammonium carbonate, $(\text{NH}_4)_2\text{CO}_3$, and bicarbonate, NH_4HCO_3 , liquid ammonia, ammonia water, ammonium sulphide, and nitrogen-phosphorus fertilizers (ammonium phosphates), nitrogen-potassium fertilizers, etc. All ammonium fertilizers are very soluble in water, their nitrogen is easily assimilated by plants.

ammonium salts. Salts containing the univalent ammonium ion, NH_4^+ ; resemble respective potassium salts in structure, colour, and other properties.

Properties: all ammonium salts are soluble in water, fully dissociate in aqueous solutions. Typical salts. Evolve gaseous NH_3 under the action of alkalis. Decompose at elevated temperatures.

Derivation: from reactions of NH_3 or NH_4OH with acids.

Uses: ammonium nitrate (Norway saltpeter), NH_4NO_3 , is

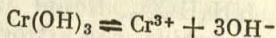
used as nitrogen fertilizer and in the production of explosives (ammonites); ammonium sulphate, $(\text{NH}_4)_2\text{SO}_4$, is a cheap nitrogen fertilizer; ammonium bicarbonate, NH_4HCO_3 , and carbonate, $(\text{NH}_4)_2\text{CO}_3$, are used in the food industry, in dyeing, in the production of vitamins, in medicine; ammonium chloride (sal ammoniac), NH_4Cl , in galvanic cells (dry batteries), for soldering and tinning, in the textile industry, as a fertilizer, and for veterinary purposes.

ammophos. A concentrated soluble fertilizer containing nitrogen and phosphorus. Made by the neutralization of phosphoric acid with ammonia. Contains about 10 to 12% N and 45 to 52% P_2O_5 . Mainly consists of monobasic ammonium phosphate, $\text{NH}_4\text{H}_2\text{PO}_4$, and, in part, dibasic ammonium phosphate, $(\text{NH}_4)_2\text{HPO}_4$.

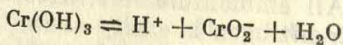
amorphous carbon. Exceedingly fine graphite powder.

amorphous substances [Gk *a-*, without + *morphe*, form]. Substances having no crystalline structure. Unlike crystals do not split to faceted particles, isotropic, that is do not show different properties in different directions, have no melting points. Examples are silicate glass, natural and synthetic resins, glue, etc.

amphoteric [Gk *amphoteris*, both]. Capable of showing both acidic and basic properties depending on the conditions. For example, water dissociates to give H^+ and OH^- ions ($\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$). The $\text{Al}(\text{OH})_3$, $\text{Cr}(\text{OH})_3$, $\text{Zn}(\text{OH})_2$, etc. hydroxides are also amphoteric. Depending on the conditions they dissociate to give either H^+ or OH^- ions, e.g.:



(basic dissociation) and

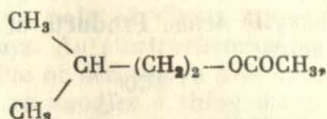


(acidic dissociation).

amygdalin [Gk *amygdale*, almond]. A glucoside. Decomposes to glucose, benzoic aldehyde, and hydrocyanic acid under the action of acids. Found in bitter almond seeds, in seeds of apricot, plum, and cherry. Used in medicine.

amyl acetate (amylacetic ester) $\text{CH}_3(\text{CH}_2)_4\text{OCOCH}_3$. Used as a solvent of many organic substances, in the production

of lacquers, synthetic silk, fruit essence. Iso-amyl acetate.



is employed as a solvent for nitrocellulose in the manufacture of photographic film and celluloid products. Also used in the food industry (pear essence).

amyl alcohol $\text{C}_5\text{H}_{11}\text{OH}$ and its isomers.

Properties: colourless liquids with a disagreeable odour.

Derivation: by distillation of fusel-oil; from gaseous products of cracking of petroleum.

Uses: the synthesis of esters for the manufacture of perfumes such as amyl acetate, the production of smokeless gunpowder, food essences. Also used as a solvent for resins, gum, etc.

amylase [Gk *amylon*, starch]. An enzyme catalyzing the hydrolysis of starch, very common in nature (in tissues of animals and plants). For example, amylase from saliva converts starch to maltose in several minutes.

amyloid. A substance resembling starch; a polysaccharide formed in incomplete hydrolysis of cellulose. Used, e.g. in the manufacture of parchment-like paper.

anabesine $\text{C}_{10}\text{H}_{14}\text{N}_2$ (neonicotine). A naturally occurring alkaloid, found in tobacco plants.

Uses: anabesine sulphate is used as an insecticide for spraying fruit and vegetable plants; anabesine is a starting material for the synthesis of nicotinic acid.

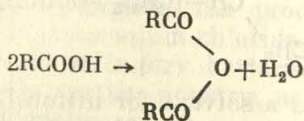
analysis [Gk *analysis*, a resolution of a whole into parts] A combination of techniques for qualitative and quantitative determination of compositions of substances. Technical analysis plays an important part in controlling technological processes.

analytical chemistry. A science treating of methods of the determination of the chemical composition of substances. A distinction is made between qualitative and quantitative analysis. Depending on the substance to be studied, the analytical chemistry is conventionally divided into the inorganic and organic analysis.

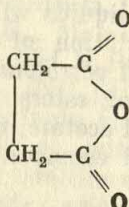
andesite, a quartz-free igneous rock, stable to the action of acids and heat. Used for lining chambers in the con-

tact and chamber processes for the manufacture of sulphuric acid, etc.

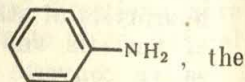
anhydrides of carboxylic acids. Products of the dehydration of carboxylic acids:



Examples are acetic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$, benzoic anhydride, $(\text{C}_6\text{H}_5\text{CO})_2\text{O}$, succinic anhydride



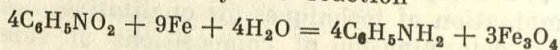
aniline (phenylamine, aminobenzene)



simplest aromatic amine.

Properties: colourless oily liquid, rapidly becomes brown on exposure to air because of oxidation, b.p. 184 °C. Slightly soluble in water, miscible with ethanol, ether, benzene; poisonous. A weak base.

Derivation: first obtained by Zinin in 1842, by the reduction of nitrobenzene with ammonium sulphide. In industry, is made by the reaction



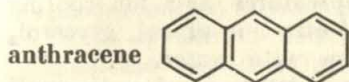
Uses: the oxidation of aniline gives a black precipitate called black aniline, a very stable black dye. Aniline is one of the most important products of chemical industry. Applied in the manufacture of various organic compounds, aniline dyes, various azo dyes, pharmaceuticals.

anion [Gk *ana-*, up + *iendi*, to go]. A negatively charged ion such as OH^- , Cl^- , SO_4^{2-} , PO_4^{3-} . In an electric field, anions go to the positive electrode, anode. Anions occur in solutions of most salts, acids and bases, in crystal lattices of ionic compounds, and in melts.

anion exchangers. See *ion exchangers*.

anode [Gk *ana-*, up + *hodos*, a way]. An electrode connected to the positive pole of direct current.

anodizing of alloys. An electrochemical process for producing a protective or decorative film on surfaces of various alloys. Thus, to anodize a thing made of an aluminium alloy it is placed into an acidic electrolyte such as H_2SO_4 , H_2CrO_4 and connected to the positive pole of a current source. Oxygen evolved during the process reacts with aluminium to produce an oxide film on its surface.

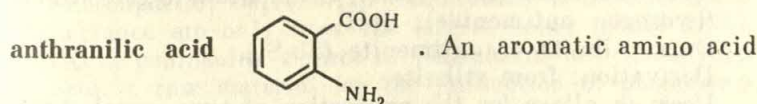


Properties: colourless crystals, m.p. 217°C , insoluble in water, soluble in hot benzene. An analogue of naphthalene (readily undergoes nitration, sulphonation, etc.) but easier to oxidize and more apt to enter addition reactions.

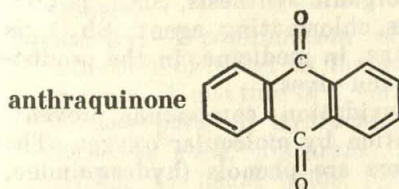
Derivation: from coal tar.

Uses: a starting material for the production of anthraquinone and numerous dyes.

anthracite. The oldest form of coal, characterized by a high density and glittering. Contains 95% carbon. Used as high-caloric solid fuel.



whose derivatives are used in the production of dyes and synthetic perfumes.



Properties: yellow crystals soluble in nitrobenzene, aniline; m.p. 286°C .

Derivation: by the oxidation of anthracene.

Uses: anthraquinone derivatives are used as dyes.

antibiotics [anti + Gk *bios*, life]. Substances of biological origin, of diverse chemical nature, which are capable of preventing growth of bacteria or even of destroying them. Antibiotics produced by cultures of moulds (penicillin), actinomycetes (streptomycin etc.), bacteria (gramicidin), and higher plants (fungicides) are known.

antifreeze. A liquid of low freezing point, employed in units operating at low temperatures and for cooling engines. Made of mixtures of ethylene glycol, glycerol, alcohols, and other substances with water.

antiknock compounds. Substances added to gasoline in small (below 1%) amounts to prevent explosive combustion (knocking). The most familiar of these is tetraethyllead, $\text{Pb}(\text{C}_2\text{H}_5)_4$.

antimony (*L stibium*) Sb. A Group V element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 51, atomic mass 121.75. One of the earliest known elements.

Properties: silvery brittle metal, m.p. 630°C . Insoluble in HCl and H_2SO_4 ; oxidation states in compounds -3 , $+3$, $+5$; at elevated temperatures, reacts with oxygen, halogens, sulphur, arsenic, and phosphorus; forms two oxides: Sb_2O_3 (Sb_4O_6), amphoteric, and Sb_2O_5 . Acids react with metal (Zn, Al, etc.) antimonides to give stibine (hydrogen antimonide), SbH_3 .

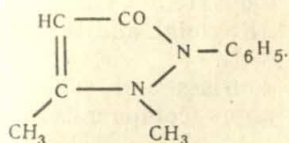
Ores: stibnite or antimonite (Sb_2S_3).

Derivation: from stibnite.

Uses: in alloys for the production of type metal, bearing metal (babbitt), the manufacture of semiconductors (AlSb , GaSb). Antimony compounds also have practical applications. In the organic synthesis, SbCl_3 is used as catalyst and SbCl_5 as chlorinating agent; Sb_2O_5 is used in the rubber industry, in medicine, in the production of glass, ceramics, and dyes.

antioxidizers. Inhibitors of oxidation, compounds preventing or decelerating oxidation by molecular oxygen. The most familiar antioxidants are phenols (hydroquinone, β -naphthol, etc.), aromatic amines (α -naphthylamine etc.). Used to protect rubber from aging, as admixtures to gasoline, for preserving fats.

antipyrine (1,5-dimethyl-2-phenyl-3-pyrazolone)



Properties: colourless crystals with a bitter taste, very soluble in water, ethanol, and chloroform.

Uses: a starting material for the synthesis of aminophenazone and novaminsulphon; in the analytical chemistry, applied to determine a number of elements, in medicine to reduce fever, relieve pain.

antiseptics [anti + Gk *sepsis*, putrefaction]. Compounds which inhibit or stop the growth of microorganisms, prevent putrefaction. Widely applied in medicine, e.g. iodine, chloramine, phenol, in the food industry (salts of benzoic, acetic, and salicylic acids), in household (phenol or carbolic acid). Antiseptics are also used for impregnating sleepers, textile materials, leather (salts of hydrofluoric and silicofluoric acids, arsenic and mercury compounds, blue vitriol, anthracene oil, phenol derivatives).

antivitamins [anti + L *vita*, life]. A group of organic substances suppressing the biological activity of vitamins.

apatite. A mineral containing phosphorus, most frequently fluoroapatite, $\text{Ca}_5\text{F}(\text{PO}_4)_3$. Occurrences of industrial importance are only rare, the largest being in the USSR (Kola peninsula). Source of phosphorus and phosphoric acid, a raw material for the production of phosphorus fertilizers, used in metallurgy.

aquamarine [L *aqua marina*, sea water]. A transparent variety of beryl, colour bluish-green or blue. A precious stone.

aquametry. A combination of techniques for the determination of water in inorganic and organic substances.

aqua regia. A mixture of 1 volume part of nitric acid and 3 volume parts of hydrochloric acid. A strong oxidant, dissolves gold, platinum, and some other metals insoluble in usual acids.

argentite (silver glance) Ag_2S . A mineral, silver ore.

argon [Gk *a-*, without + *ergon*, work] Ar. A Group VIII element of the 3rd period of the Mendeleev Periodic

Table of Elements, atomic number 18, atomic mass 39.948. A rare gas. Occurs to the extent of 0.93% of the atmosphere. Discovered by D. Rayleigh and W. Ramsay in 1894.

Properties: monatomic gas, colourless and odourless. Reactions: inert; a number of argon compounds were, however, synthesized.

Uses: inert gas shield in metallurgical and chemical processes; filling incandescent and fluorescent lamps, gas-discharge tubes (give blue light); in electronics and nuclear equipment (ionization counters and chambers). The determination of the $^{40}\text{Ar}/^{40}\text{K}$ ratio in minerals containing potassium enables the age of geological formations and meteors to be estimated.

Armco iron. Technically pure iron containing very little carbon and other impurities. Stable to corrosion, has increased electric conductivity and exceedingly high ductility. Used in electromagnet cores, relay elements, in the production of alloys.

aromatic hydrocarbons. Hydrocarbons containing benzene rings (isolated and fused). May contain saturated and unsaturated side chains as substituents. The most important aromatic compounds are benzene, C_6H_6 , and its homologues: toluene, $\text{C}_6\text{H}_5\text{CH}_3$, xylene, $\text{C}_6\text{H}_4(\text{CH}_3)_2$, etc.; naphthalene, C_{10}H_8 ; anthracene, $\text{C}_{14}\text{H}_{10}$, and their derivatives. The characteristic chemical properties are increased stability of the aromatic nucleus, and the propensity to enter substitution reactions. The major sources of aromatic hydrocarbons are coal tar and petroleum. The synthetic methods are also of importance. Aromatic hydrocarbons are starting materials for the preparation of ketones, aldehydes and acids of the aromatic series, and of many other substances.

aromatics. Organic substances with a characteristic pleasant odour, used in perfumery, cosmetics, as components of soaps, food-stuffs to add a certain smell to these products. Widely distributed in nature, found in essential oils, aromatic resins, and other complex mixtures of organic substances extracted from natural products of plant and animal origins. Many aromatics are made synthetically: the first to be synthesized were vanillin, indole, etc. Esters of acetic, valeric, salicylic, anthranilic, and cinnamic acids have found practical applications.

aromatization. The formation of aromatic hydrocarbons from compounds belonging to other classes. Occurs under the conditions of biochemical syntheses in plants, animals, and microorganisms. In industry, the aromatization of petroleum products is widely applied to increase percentage of aromatic hydrocarbons.

arsenate. A metal salt of arsenic acid, H_3AsO_4 . The chemical properties of arsenates resemble those of metal phosphates. Alkali metal and ammonium arsenates are only soluble in water.

arsenic [Gk *arsenikos*, strong, masculine] As. A Group V element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 33, atomic mass 74.9216. Has one stable isotope, ^{75}As . Natural arsenic compounds were known to the ancients.

Properties: exists in several allotropic forms, the most stable one under usual conditions is metallic or grey arsenic. Arsenic derivatives are highly poisonous.

Reactions: usually occurs in compounds in the oxidation states +5, +3, -3. Undergoes oxidation to As_2O_3 when heated in the air. Gives metal arsenides on alloying with metals.

Ores: the most important mineral is arsenopyrite, $FeAsS$.

Uses: free arsenic is of limited use in the production of certain alloys, e.g. in the manufacture of lead bullets. Arsenic compounds are widely applied in agriculture as means against vermins, in medicine.

arsenic compounds. Arsenic trioxide (white arsenic), As_2O_3 , is used as hide preservative, in the manufacture of glass and other arsenic compounds. Reacts with alkalis to give arsenites. Arsenic pentoxide, As_2O_5 , gives arsenic acid, H_3AsO_4 , in aqueous solutions. Arsenic acid salts are called arsenates. Arsenic hydride (arsine), AsH_3 , is a colourless gas, smells like garlic, extremely poisonous. A large number of organoarsenic derivatives have been synthesized.

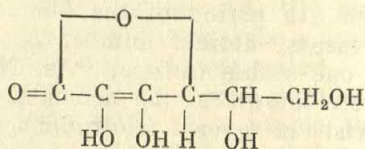
arsenites and metaarsenites. Salts of arsenous and metaarsenous acids, H_3AsO_3 and $HAsO_2$. Alkali metal and ammonium arsenites and metaarsenites are only soluble in water. Very poisonous. Used to kill insects.

aryl. A univalent radical of the aromatic series such as C_6H_5 , phenyl, $C_{10}H_7$, naphthyl, etc.

asbestos. A group of minerals that occur in fibrous form. According to their chemical composition, these minerals are various hydrated magnesium, iron, calcium, and sodium silicates: $\text{Mg}_6(\text{Si}_4\text{O}_{11})(\text{OH})_6\text{H}_2\text{O}$; $2\text{Na}_2\text{O} \cdot 6(\text{Fe}, \text{Mg})\text{O} \cdot 2\text{Fe}_2\text{O}_3 \cdot 17\text{SiO}_2 \cdot 3\text{H}_2\text{O}$. Asbestos fiber is used in the manufacture of chemical filters, tarpaulin, protective clothing for firemen, paper, cardboard, building materials.

ascarite. Asbestos impregnated with molten NaOH. Used to absorb CO_2 .

ascorbic acid (vitamin C)



Properties: colourless crystals, soluble in water. Exhibits reducing properties.

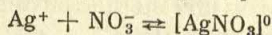
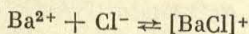
Derivation: synthetically from glucose.

Uses: plays an important part in biochemical redox processes; facilitates the formation of deoxyribosenucleic acid. Is not synthesized in man, but must be present in the diet to prevent scurvy. Of plants, wild rose, black currant, citrus fruits, vegetables, pine and fir needles are most rich in ascorbic acid.

asphalt. A mixture of bitumens and mineral substances. Used for paving and as a dielectric.

aspirin. See *acetylsalicylic acid*.

association [L *associare*, to join to, unite with]. Binding of simple molecules or ions into more complex species which does not affect the chemical nature of a substance. A distinction is made between association of ions and association of molecules. The formation of ionic associates depends on electrostatic forces. The simplest ionic associates contain two or three ions and are neutral or charged particles:

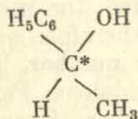
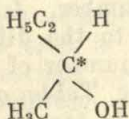
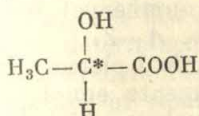


Association of molecules is caused by the action of intermolecular forces; it occurs, e.g. in water, $(\text{H}_2\text{O})_x$ (see *hydrogen bond*). Association influences the properties of

solutions and plays an important part in the formation of complex compounds.

astatine [Gk *astatos*, unstable] At. A radioactive element, placed in the VII Group, 6th period of the Mendeleev Periodic Table of Elements, atomic number 85, the longest lived isotope is ^{210}At ($T_{1/2}$ is 8.3 years). First isolated by Segré from the reaction $^{209}\text{Bi}(\alpha, 3n)^{210}\text{At}$ (by the irradiation of bismuth by alpha particles) (1940). The chemical properties of astatine resemble those of iodine.

asymmetric atom. An atom of a polyvalent element such as carbon, nitrogen bearing dissimilar atomic groups or atoms of other elements as substituents. Examples of asymmetric carbon atoms are as follows



(the asymmetric atoms are labelled by asterisk).

atom (Gk *atomos*, indivisible). The smallest particle retaining the chemical properties of an element. Each element contains atoms of its own kind; their structure determines the individual characteristics of the element. Atoms consist of a positively charged nucleus and negatively charged electrons, the total charge being zero. Atoms can exist in the free state and in combinations with atoms of the same element or other elements (in molecules).

atomic bond. See *covalent bond*.

atomic mass. The mass of an atom in atomic mass units. The use of a special mass unit for measuring atomic masses is needed because of their smallness (10^{-22} to 10^{-24} g) which makes such units as gram inconvenient. Atomic mass unit is defined as $1/12$ of the mass of the ^{12}C isotope; it is approximately equal to $(1.66043 \pm \pm 0.00031) \cdot 10^{-24}$ g. Usually, atomic masses are written without indicating the unit in which it is measured. For one-isotope elements such as ^{19}F , ^{27}Al , the atomic mass of the element coincides with the atomic mass of the isotope. If an element consists of a mixture of isotopes, its atomic mass is calculated as an average of atomic masses of individual isotopes with taking into

consideration their abundances. For example, natural chlorine is a mixture of the isotopes ^{35}Cl (75.53%) and ^{37}Cl (24.47%) whose masses are equal to 34.964 and 36.961, respectively. The atomic mass of chlorine is

$$\frac{34.964 \times 75.53 + 36.961 \times 24.47}{100} = 35.453$$

atomic nucleus. A part of an atom containing most of its mass, positively charged. Consists of protons and neutrons. The positive charge of a nucleus is equal to the number of protons it contains, Z . That number coincides with the number under which a given element appears in the Mendeleev Periodic Table of Elements. The sum of the number of protons and the number of neutrons is called the mass number, A . The number of neutrons is therefore equal to the difference, $A - Z$.

atomic number. The number of a chemical element in the Mendeleev Periodic Table of Elements equal to the number of protons in the atomic nucleus which in turn is equal to the number of electrons in the atom, Z . The atomic number determines the charge of the nucleus equal to Ze^+ , where e^+ is the elementary positive electric charge (the charge of the positron).

atomic radius. A quantity giving an approximate characteristic of the size of an atom. Within a row of the Mendeleev Periodic Table of Elements, an increase in the atomic number is accompanied by a decrease in the atomic radius because of an increase in the nuclear charge.

atropine $\text{C}_{17}\text{H}_{23}\text{O}_3\text{N}$. An alkaloid contained in *Datura* and *belladonna*, stimulates breathing, dilates the pupil of the eye. Used as antidote.

augite [Gk *auge*, bright, shining]. A rock-forming mineral of the pyroxene family, $\text{Ca}(\text{Mg}, \text{Fe}, \text{Al}) [(\text{Si}, \text{Al})_2\text{O}_6]$. Colour from green to black. Hardness 5 to 6. A constituent of andesite, basalt, diabase, and other igneous rocks, predominantly of basic nature.

autoclave [auto + L *clavis*, key]. A leakproof container for carrying out physicochemical processes under pressure; may be of different shapes. Used in the chemical industry to run reactions at elevated temperature and pressure, for sterilizing nutrient media, instruments, in the manufacture of building materials, in the food industry.

autolysis [auto + *Gk lysis*, a loosening]. The self-destruction of substances (proteins, carbohydrates, fats) in organisms under the action of enzymes contained in cells. Autolysis occurs when the cells are frozen, dried, poisoned, e.g. by toluene, chloroform. Autolysis also goes in some industrial processes (ripening of dough, ensilage).

auxin [*Gk ausein*, to increase, grow]. Any of substances stimulating plant growth. See also *heteroauxin*.

Avogadro's law. Equal volumes of all gases under identical conditions of temperature and pressure contain equal numbers of molecules. Formulated in 1811 by the Italian physicist Amedeo Avogadro. The law only holds strictly with ideal gases. According to it, one mole of any gas occupies 22.4 litres under the standard conditions (0 °C, 10^5 Pa). The law enabled true atomic masses of elements to be determined. It is used in calculations based on chemical formulas and reaction equations, in the determination of relative molecular masses of gases.

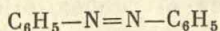
Avogadro's number. The number of molecules contained in one mole of any substance. Symbol: L or N_A .

$$N_A = 6.02 \cdot 10^{23} \text{ mole}^{-1} = 6.02 \cdot 10^{26} \text{ kmole}^{-1}.$$

azeotropic mixture. A uniform constant boiling mixture which distils at a constant composition, such as a mixture of ethanol (96 %) with water (4 %) boiling at 78 °C and 10^5 Pa. A change in pressure changes the composition as well as b.p. of an azeotropic mixture, which distinguishes such mixtures from pure liquids.

azides of metals. Salts of hydrazoic acid, HN_3 , e.g. sodium azide, NaN_3 . Azides of some heavier metals such as lead azide, $\text{Pb}(\text{N}_3)_2$, are used as detonating compounds.

azo compounds. Organic compounds containing one or more azo groups linked with organic radicals, e.g. azobenzene



Usually made by the coupling process. A large number of azo compounds are dyes. Also used in the analytical chemistry as indicators and organic reagents.

azo dyes. Dyes containing one or several azo groups such as Congo red. Have various colours, as a rule not very fast. The most numerous group of organic dyes, used for dyeing leather, fabrics, paper, rubber, in the manufacture of lacquers, in polygraphy, in the analytical chemistry as indicators.

azo group ($-\text{N}=\text{N}-$). Contained in azo compounds, a chromophore.

azurite [Fr] (chessylite) $\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$. A blue mineral with vitreous luster, brittle. Hardness 3.5-4. Found in copper ores together with malachite.

Uses: ore of copper; the production of blue vitreol; a blue dye.

B

Babbitt (after I. Babbitt, an American inventor). An alloy with tin, lead, zinc, or aluminium as the major component; used to reduce friction in bearings, etc.

bactericide [bacteria + *L. caedere*, to kill]. Any product that will kill bacteria; bactericides include inorganic and organic substances such as halogens, nitrogen oxides, chlorine oxide, hydrogen peroxide, compounds containing copper, phenol, ethanol, antibiotics, etc.

Bakelite (after L. Backeland, an inventor). Trademark for a series of phenol-formaldehyde resins. Soluble in ethanol but prolonged heating converts it to an insoluble and infusible form. This property of Bakelite is utilized in the manufacture of plastics. Alcohol solutions of Bakelite are employed as lacquers.

barite (heavy spar) BaSO_4 . Natural barium sulphate. Uses: transparent barite crystals are used in optical instruments; employed as protection from X-rays, as a material for coatings in the chemical industry because of its high chemical stability, in particular towards sulphuric acid. A raw material for the production of barium salts, white pigments, enamels; used as filler in the manufacture of rubber, oilcloth, linoleum, and paper.

barium [Gk *barys*, heavy] Ba. A Group II element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 56, atomic mass 137.34. An alkaline earth metal. Discovered by Scheele in 1774.

Properties: soft silvery-white metal, m.p. 850°C . An active metal, readily undergoes oxidation in the air, vigorously reacts with water to give barium hydroxide, reacts directly with many elements. In compounds, occurs in the state $+2$.

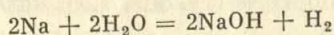
Occurrence: as barite, BaSO_4 , witherite, BaCO_3 .

Uses: barium and its alloys are used to absorb gases in electron tubes, barium oxide in the manufacture of cathodes. The most important barium compounds are barium peroxide, BaO_2 (catalysis, the preparation of H_2O_2 and bleaches), barium hydroxide, Ba(OH)_2 (absorption of CO_2), barium carbonate (the synthesis of other barium compounds, glass industry, enamels, glaze), barium chloride, $\text{BaCl}_2 \cdot 2\text{H}_2\text{O}$ (rat and vermin poison, the manufacture of leather), barium sulphate, BaSO_4 (white pigment, strongly absorbs γ -rays, indicator in X-ray photography). Barium compounds turn flame green.

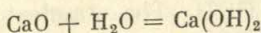
barium hydroxide, solution. A solution of Ba(OH)_2 saturated at room temperature; used to absorb CO_2 .

basalt. A volcanic rock containing 50% SiO_2 , 16% Al_2O_3 , and a number of other oxides. A very firm, durable and chemically stable material. Used as building stone, in the manufacture of glass and ceramics.

base. A substance whose molecule contains a metal ion and one or several hydroxyl groups. Dissociates in aqueous solutions with the formation of hydroxyl ions, OH^- . Formed in the reaction of some metals with water:



or some basic oxides with water



Bases readily soluble in water are called alkalis. According to another definition a base is an acceptor of protons.

bauxite. $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$. Minerals containing aluminium hydroxide and impurities (iron and titanium compounds). Depending on the percentage of iron, have various colours, usually red or grey. Industrial uses include the production of aluminium and its chemicals.

benzaldehyde (benzoic aldehyde, benzenecarbonal*) $\text{C}_6\text{H}_5\text{CHO}$. The simplest aromatic aldehyde. Properties: liquid with an odour resembling bitter almonds.

Occurrence: found in bitter almond, bird-cherry leaves.

Uses: the synthesis of dyes, perfumes.

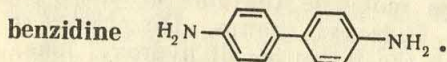


The simplest aromatic hydrocarbon.

Properties: colourless mobile liquid with characteristic odour, insoluble in water, m.p. $5.5^\circ C$, b.p. $80.1^\circ C$. Very soluble in ethanol, ether, chloroform, dissolves fats and oils, resins, rubber, etc. Burns, reacts with Cl_2 and HNO_3 to give the substitution products, C_6H_5Cl , $C_6H_5NO_2$.

Derivation: from coal-tar oil.

Uses: the synthesis of many organic substances, the production of aniline and aniline dyes, pharmaceuticals. Also employed in the manufacture of plastics, explosives, as a solvent, etc. Very active physiologically; at high concentrations, benzene vapour is harmful to the central nervous system.



Properties: colourless crystals, turn dark on exposure to air and light.

Uses: an important dye-stuff intermediate; used in the analytical chemistry to determine a number of oxidizers.

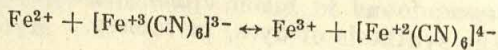
benzoic acid C_6H_5COOH . The simplest carboxylic acid of the aromatic series.

Properties: colourless crystals, slightly soluble in water, soluble in ethanol.

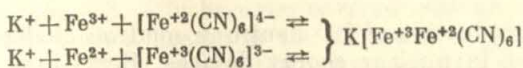
Uses: the organic synthesis, the manufacture of dyes, medicine.

berkelium (from Berkeley, USA, where first isolated at the University of California) Bk. A synthetic radioactive element of the actinide series, atomic number 97. Isolated in 1950. Occurs in the oxidation states $+3$, $+4$.

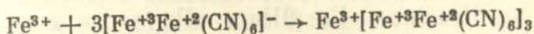
Berlin blue. Turnbull's blue. Berlin blue is formed in the reaction of $[Fe^{+2}(CN)_6]^{4-}$ and Fe^{3+} , Turnbull's blue in the reaction of $[Fe^{+3}(CN)_6]^{3-}$ and Fe^{2+} . Both products have practically the same composition



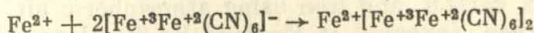
At a 1:1 mole ratio, a colloid solution of "soluble" Berlin blue is formed:



In the presence of excess Fe^{3+} the reaction



occurs, insoluble Berlin blue is precipitated. In the presence of excess Fe^{2+} the reaction



occurs; to give a precipitate of insoluble Turnbull's blue. Insoluble precipitates of both compositions are destroyed by solutions of alkalis.

Uses: Berlin blue is used in the manufacture of oil dyes, enamel dyes, etc.

Berthollett's salt. See *potassium chlorate*.

berthollide (named after Berthollet). A compound of variable composition, see *deltonide*.

beryl [Gk *beryllos*, sea-green gem]. A mineral, beryllium silicate, $Al_2Be_3 \cdot Si_6O_{18}$.

Properties: vitreous luster, brittle, hardness 7.5-8.0. Unattacked by acids except for hydrofluoric acid.

Uses: source of beryllium and its salts, gem stone. Depending on colour, classified as beryl proper (greenish-blue), aquamarine (transparent blue), heliodor (yellow), emerald (bright green), morganite (pink). Of these, emerald, aquamarine, and heliodor are used as jewelry.

beryllium (first called glucinium, from Gk *glykys*, sweet) Be. A Group II element of the 1st period of the Mendeleev Periodic Table of Elements, atomic number 4, atomic mass 9.0122, includes one stable isotope, 9Be . Discovered by Vauquelin in beryl (1798).

Properties: a hard silvery-white metal, m.p. 1280 °C. Beryllium metal and its compounds are strong poisons. In compounds occurs in the oxidation state +2; slowly undergoes oxidation in the air with the formation of a protective BeO film, soluble in hydrochloric and sulphuric acids, reacts with alkalis. Beryllium oxide is a white powder insoluble in water, BeO . Beryllium hydroxide, $Be(OH)_2$, shows amphoteric properties.

Derivation: by electrolysis of molten beryllium chloride or beryllium fluoro-oxide; the most important source is beryl.

Uses: production of fast neutrons, neutron moderator and reflector in nuclear energy devices. Beryllium bronzes, copper beryllium alloys containing up to 2.5% beryllium and 0.2 to 0.5% admixtures of Ni and Co have wide technical applications. Beryllium alloys are employed in aircraft and rocket engineering, in electrical technology.

Bessemer process. A method for the production of steel from pig iron in a converter by the oxidation of silicon, manganese, carbon, and iron using atmospheric air enriched in oxygen. Invented in England by Sir Henry Bessemer (1856).

beta particles. Electrons (β^-) or positrons (β^+) ejected from the nucleus of a radioactive isotope as a result of β -decomposition. Streams of such particles are called beta rays. They deviate from straight-line propagation direction in electric and magnetic fields. Beta particles are emitted at speeds approaching the speed of light. Can ionize gases, induce chemical reactions, luminescence, act on photographic plates.

bicarbonates. See *hydrocarbonates*.

biochemistry [Gk *bios*, life + chemistry]. Biological chemistry, the science that deals with the chemical composition of living organisms and chemical transformations of substances in vivo. Biochemistry is subdivided into the biochemistry of man, the biochemistry of plants, and the biochemistry of microorganisms. At present, the principal metabolism processes in animals, plants, and microorganisms have been shown to have a common nature.

biogeochemistry. A branch of study dealing with the role played by living organisms in migration, distribution, scattering, and concentration of chemical elements in earth's crust (biosphere).!

bismuth [Gk *Wiss Mat*, a white mass] Bi. A Group V element of the 6th row of the Mendeleev Periodic Table of Elements, atomic number 83, atomic mass 208.980. One stable isotope, ^{209}Bi , occurs in nature. Known from the 16th century, but was believed to be a variety of tin, antimony, and lead. Was shown to be an individual element in the middle of the 18th century.

Properties: a silvery-white metal, brittle, easy to crumble into powder, m.p. 271 °C. The oxidation states in compounds +3, +5; becomes covered with an oxide film in wet air; when heated in the air burns to produce bismuth oxide, Bi_2O_3 ; insoluble in hydrochloric and diluted sulphuric acids, easily dissolved under the action of nitric acid or a mixture of HCl and HNO_3 . Combines directly with sulphur and halogens.

Uses: bismuth metal is used as a component of low-melting alloys, in nuclear energy devices as heat-transfer agent, etc. Bismuth compounds are used in medicine.

bisulphates. See *hydrosulphates*.

bisulphites. See *hydrosulphites*.

blueing. The preparation of films of Fe_3O_4 and other oxides on the surface of usually low-alloy and high-carbon steel for protective and decorative purposes.

bog ore. See *vivianite*.

bone-meal. Ground animal bones, used as a phosphorus fertilizer (contains 29 to 34% P_2O_5).

borates. Metal salts of tetraboric acid, $\text{H}_2\text{B}_4\text{O}_7$, or metaboric acid, HBO_2 . Occur in nature, e.g. borax, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$. Calcium borate is used in the manufacture of ceramics, zinc borate in the textile industry.

borax (sodium tetraborate) $\text{Na}_2\text{B}_4\text{O}_4 \cdot 10\text{H}_2\text{O}$. A natural boron mineral.

Properties: transparent crystals, fully lose water at 400 °C. Undergoes hydrolysis in water solutions to give an alkaline reaction; reacts with many metal oxides with the formation of coloured compounds (beads).

Uses: the manufacture of enamels, optical and coloured glasses, as a flux in soldering, in the paper and pharmaceutical industries. Also employed as a disinfectant, a preservative. In the analytical chemistry, serves as a standard substance for the determination of concentrations of solutions of acids and for other purposes.

Bordeaux mixture. A mixture of slaked lime and copper sulphate solution. Used as a fungicide.

boric acid (orthoboric acid) H_3BO_3 . A weak acid, colourless odourless scales; found in nature (mineral sassolite, in hot and mineral springs). Used as boric fertilizer, as a disinfectant (medicine), for the preparation of buffer solutions (laboratory).

borides. Metal boron compounds, formed from a metal and boron at high temperatures. Very hard, durable, and corrosion resistant materials.

Boron [Ar *bauraq*, *buraq*, borax] B. A Group III element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 5, atomic mass 10.811. Exists as two stable isotopes, ^{10}B (19%) and ^{11}B (81%). First obtained by Gay-Lussac and Thenard in 1808.

Properties: Pure crystalline boron has a greyish-black colouration; the reduction of boron compounds with magnesium yields an amorphous variety; m.p. 2300 °C. The oxidation state in compounds +3; dissolves in concentrated HNO_3 ; at 700 °C combines with air oxygen to give B_2O_3 , at red heat temperature reacts slowly with water vapour producing boric acid, H_3BO_3 . Boron is a strong reducing agent; at elevated temperatures reacts with halogens. Combines with metals to give borides. Boron hydrogen compounds (boron hydrides, boranes) are colourless gases or liquids, readily undergo oxidation to release much heat.

Occurrence: boric acid, various borates.

Uses: boron trifluoride, BF_3 , is widely used in the organic synthesis; boranes are employed in rocket fuels, as polymerization catalysts, for coating metal surfaces with boron; small admixtures of boron are introduced into steel and other alloys to improve their mechanical properties. Boron and its compounds are used as controlling agents in uranium graphite piles and for protection from neutron radiation. Boron admixture is harmful to nuclear fuel and materials for nuclear energy devices, for it strongly absorbs neutrons.

brass. An alloy of copper and zinc (60-90% Cu and 40-10% Zn) containing small admixtures of Al, Si, Pb, Mn, Sn, Fe, etc. Has good mechanical properties, shows high resistance to corrosion under atmospheric conditions. Brasses are used in the manufacture of various mechanical devices, in shipbuilding, aircraft, in various instruments, and chemical apparatus.

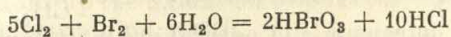
braunite $\text{Mn}_2\text{O}_3 \cdot n\text{SiO}_2$, a mineral. Used in the metallurgical and chemical industries as source of manganese.

brilliant green $\text{C}_{29}\text{H}_{33}\text{O}_4\text{N}_2$. An organic substance, gold-green powder; solutions in water and ethanol (0.1 to 2%) are used as an antiseptic.

bromides. Compounds of bromine and metals, salts of hydrobromic acid such as potassium bromide, KBr, and silver bromide, AgBr.

bromine [Gk *bromos*, stench] Br. A Group VII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 35, atomic mass 79.904; natural bromine contains two stable isotopes, ^{79}Br (50.6%) and ^{81}Br (49.4%). Discovered by Balard in 1826.

Properties: Heavy, dark, reddish-brown liquid, with a strong disagreeable odour. Solid bromine forms bright red crystals with metallic glitter; m.p. -7.3°C , b.p. 58.8°C . Soluble in many organic solvents; aqueous solutions of bromine are called bromine water. Valence -1 (bromides, KBr), $+1$ (NaBrO), $+3$ (NaBrO₂), $+5$ (bromates, KBrO₃); belongs to the halogen family, less active than chlorine but more so than iodine. Does not react with oxygen directly. Combines with hydrogen to give hydrogen bromide, HBr, whose aqueous solutions are called hydrobromic acid. Bubbling of chlorine through bromine water results in the formation of bromic acid:



Bromic acid salts, bromates, are stable under usual conditions, show oxidizing action.

Uses: the production of bromide salts and various organobromine derivatives. Bromine and its compounds are used in the synthetic organic chemistry, photography, medicine (sedatives). Bromine and bromine water are employed in chemistry as oxidizing agents.

bromoform (tribromomethane) CHBr_3 . A colourless liquid, readily decomposes in the air under the action of light. Used in the synthesis of a number of pharmaceuticals.

bronze [It]. An alloy with copper as the major component. Depending on the second base component the term is used with reference to tin, aluminium, beryllium, lead, manganese, silicon, and other alloys, "bronzes". Bronzes have good mechanical properties. Bronze for bearings contains 89.5% Cu, 10% Sn, and 0.5% Pb; bronze for gears 90% Cu and 10% Sn. Bronzes are used in the manufacture of details of mechanisms, for casting works of art, etc.

brown coal. See *lignite*.

buffer solution. A solution with a constant concentration of hydrogen ions; prepared by mixing a weak acid and its salt, e.g. CH_3COOH and CH_3COONa , or a weak base and its salt, e.g. NH_3 and NH_4Cl . Moderate amounts of either a strong acid or base may be added to such a solution without causing any large change in the pH value which also remains unaffected by dilution or concentration. Buffer solutions are widely applied in chemical studies; they play an important part in processes in vivo. Thus the constancy of pH in blood is maintained with the help of buffer mixtures containing carbonates and phosphates. A large number of buffer solutions are known (acetate-ammonia, phosphate, borate buffers, etc.).

1,3-butadiene (biviny) $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$. A colourless gas with a characteristic odour; readily polymerizes and is used in the manufacture of synthetic rubbers. In industry, butadiene is made from butane and butylenes, acetylene, and from ethanol.

butane C_4H_{10} . An odourless and colourless gas, a hydrocarbon of the paraffin series. Two isomers are known: *n*-butane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$, and isobutane, $\begin{array}{c} \text{CH}_3 \\ \diagup \\ \text{CH} \\ \diagdown \\ \text{CH}_3 \end{array} - \text{CH}_3$. Found in petroleum and natural gas. *n*-Butane is used in the synthesis of butadiene.

Butlerov's theory of chemical structure (1861). Atoms are linked with each other in molecules of organic substances to form certain sequences. Linking occurs according to the valences of the atoms involved. The properties of a substance depend not only on its qualitative and quantitative composition but also on the relative arrangement of atoms in a molecule. Molecules of each substance thus have a definite structure which determines substance's properties. The theory of the chemical structure suggested by A. M. Butlerov provided the scientific basis for the organic chemistry, it enabled the organic nomenclature to be developed and numerous organic substances to be classified. The theory by Butlerov allows the prediction of many substance properties from the structure of molecules, and the development of synthetic routes to compounds with desired properties.

butyl alcohol (butanol*) $\text{C}_4\text{H}_9\text{OH}$. A colourless liquid with a characteristic odour of fusel-oil. The isomers: primary *n*-butyl alcohol, $\text{CH}_3(\text{CH}_2)_3\text{OH}$, secondary *n*-butyl

alcohol, $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$, isobutyl alcohol, $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$, trimethylcarbinol, $(\text{CH}_3)_3\text{COH}$. *n*-Butyl acetate, $\text{CH}_3\text{COO}(\text{CH}_2)_3\text{CH}_3$, is widely used as solvent for lacquers.

butyl rubber. Synthetic rubber produced by copolymerization of isobutene with a small proportion of isoprene. A transparent elastic white substance, has good electrical insulation characteristics. Used in the manufacture of inner tires, for rubberizing fabrics, in the production of various rubber goods and electrical insulators.

butylene (butene) C_4H_8 . An olefinic hydrocarbon. All the three isomers of butylene, $\text{C}_2\text{H}_5-\text{CH}=\text{CH}_2$, $\text{CH}_3\text{CH}=\text{CHCH}_3$, and $(\text{CH}_3)_2\text{C}=\text{CH}_2$, are gases. Isolated from petroleum cracking products. Used in the production of butadiene, lubricants, and gasoline; isobutene, in the rubber industry.

butyric acid (butanoic acid*) $\text{C}_3\text{H}_7\text{COOH}$. A colourless oily liquid with a rancid odour. The two isomers known are *n*-butyric acid, $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{COOH}$, and isobutyric acid, $(\text{CH}_3)_2\text{CH}-\text{COOH}$. Ester of *n*-butyric acid and glycerol occurs in butter.

Derivation: by the oxidation of butanol, by fermentation of waste containing starch.

Uses: tanning agent in the manufacture of leather, the production of rubber. Esters of butyric acid are used in the preparation of fruit essences, e.g. ethyl butyrate serves as pine-apple essence.

C

cadmium [L *cadmia*, a zinc ore, calamine (hydrous zinc silicate)]. A Group II element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 48, atomic mass 112.40. Discovered in 1817 by Stromeyer. Properties: a silvery-white metal, soluble in acids, insoluble in alkalis. The oxidation state in compounds +2. The most important compounds are CdO , CdS , $\text{CdCl}_2 \times \text{H}_2\text{O}$, and $3\text{CdSO}_4 \cdot 8\text{H}_2\text{O}$. Cadmium salts are colourless, give acid solutions.

Derivation: as a by-product in lead, zinc, and copper production.

Uses: control and emergency rods in nuclear reactors, alkaline storage batteries, cadmium alloys, protective coatings (cadmium plating).

caffeine. An alkaloid contained in tea leaves and coffee beans. White crystals with a bitter taste, odourless. Caffeine salts, caffeine sodium benzoate and caffeine sodium salicylate, are used in medicine to stimulate central nervous system activity.

calcined soda. See *soda*.

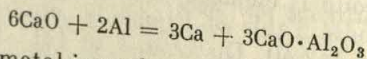
calcite. See *limestone*.

calcium [L *calx*, *calcis*, lime] Ca. A Group II element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 20, atomic mass 40.08. An alkaline earth metal. Natural calcium compounds such as limestone, marble, gypsum, and also lime produced by the calcination of limestone have been used as building materials from ancient times. Calcium metal was first prepared by Davy in 1808.

Properties: a silvery white metal, the oxidation state in compounds +2. Calcium metal is very reactive; it is a strong reducing agent, at elevated temperatures displaces almost all metals from their oxides, sulphides, and halides. At room temperature, readily reacts with oxygen to give CaO which combines with water with the formation of a strong base, Ca(OH)₂. Vigorously reacts with acids to release hydrogen, reacts with halogens and dry hydrogen with the formation of calcium hydride, CaH₂. Heating of calcium together with graphite yields calcium carbide, CaC₂.

Occurrence: found in sedimentary rocks and in various minerals; the chief ores are limestone and chalk.

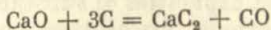
Derivation: by electrolyzing molten CaCl₂ or reducing calcium oxide with aluminium metal under vacuum and elevated temperature:



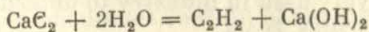
Uses: pure metal is used as a reducing agent for the preparation of Cs, Rb, Cr, U, Zr, Th, and V metals from their compounds; for oxidizing steels calcium alloys with lead are used to reduce friction. Calcium minerals have found wide applications; limestone is used in the manufacture of lime ash, cement, silicate bricks, and as a building material; it is also employed in metallurgy (flux), in

the chemical industry (the production of calcium carbide, soda, caustic soda, chlorinated lime, fertilizers), in the manufacture of sugar and glass. Chalk, marble, Iceland spar (calcite), gypsum, fluorite, etc. are also important materials. See *calcium compounds*.

calcium carbide CaC_2 . A compound of calcium and carbon. First obtained in 1862 by Wöhler who heated a zinc-calcium alloy with coal. Now made by the interaction of CaO with coke and anthracite in an electric furnace:



Reacts with water with the evolution of acetylene:



Calcium carbide is extensively used as source of acetylene, in the manufacture of calcium cyanamide (made by heating CaC_2 in the flow of N_2), and for reducing alkali metals.

calcium compounds. Calcium arsenate, $\text{Ca}_3(\text{AsO}_4)_2$, poisonous, used as an insecticide; calcium arsenite, $\text{Ca(AsO}_2)_2$, used against locust and rodents (has a strong burning action on plants, poisonous); calcium hydride, CaH_2 , a reducing agent (the organic chemistry, metallurgy); calcium chloride, CaCl_2 , absorbs moisture, used in medicine; calcium carbonate, CaCO_3 , a filler for paper, rubber, linoleum; natural CaCO_3 and calcium sulphate, CaSO_4 , are used as building materials; calcium phosphates (neutral, $\text{Ca}_3(\text{PO}_4)_2$, monohydro, CaHPO_4 , and dihydro, $\text{Ca(H}_2\text{PO}_4)_2$, phosphates) are used in the manufacture of ceramics and glass, in dentistry (toothpaste), as phosphorus fertilizers, as soft abrasives; calcium cyanamide, CaCN_2 , is a nitrogen fertilizer, also used for stripping plants of leaves before harvesting and as a weed-killing agent; calcium hypochlorite, Ca(ClO)_2 , is employed for bleaching fabrics and cellulose, and as an oxidizer in chemical processes.

calcium cyanamide. See *calcium compounds*.

calcium oxide CaO . Colourless crystals, vigorously reacts with water with release of much heat and formation of calcium hydroxide, Ca(OH)_2 , which is a strong base and can absorb CO_2 from the atmosphere. See also *lime*.

californium (from University of California) Cf. A synthetic radioactive element of the actinide series, atomic num-

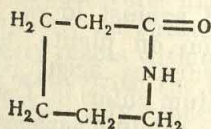
ber 98, mass number of the longest lived isotope 251. Discovered in 1950 by Thompson, Street, Chiorso, and Seaborg. The oxidation state +3.

calomel (mercurous chloride) Hg_2Cl_2 . A white powder, tasteless and odourless, insoluble in water, ethanol, and organic solvents. Used in medicine.

calorimetry [L *calor*, heat + *metry*, to measure]. A combination of procedures for measuring heat evolved or absorbed in various physical and chemical processes, employed to determine heat capacities of substances, thermal effects of chemical reactions, dissolution, wetting, adsorption, radioactive decay, etc. The calorimetric techniques are also extensively used in industry to determine the heating power of various fuels.

camphor. A colourless crystalline substance with a characteristic odour, insoluble in water, soluble in organic solvents. Obtained from the camphor-tree wood. Synthetic camphor is made from spirits of turpentine. Used as a pharmaceutical.

caprolactam. Epsilon-caprolactam



Properties: white crystals, very soluble in water, ethanol, ether, and benzene. Polymerizes to a polyamide resin when heated in the presence of small amounts of water, ethanol, amines, carboxylic acids, or some other compounds.

Derivation: from benzene as starting material; can also be obtained from non-aromatic products such as furfural, acetylene, ethylene oxide, propylene, butadiene, etc.

Uses: the manufacture of nylon fibre.

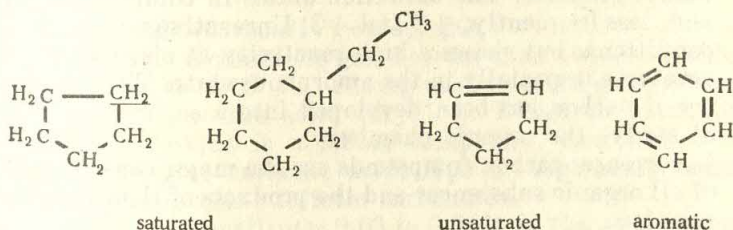
carbamide. See *urea*.

carbide. A binary compound of carbon. Carbides are high-melting solids, insoluble in any of the solvents known. Boron and silicon carbides (B_4C and SiC), and also titanium, tungsten, and zirconium carbides (TiC , WC , and ZrC) are very hard, refractory, and chemically inert substances. Carbides are used in the manufacture of various kinds of pig iron and steel, alloys, as refractories

and abrasives, as reducing agents, deoxidizers, catalysts, etc. Tungsten and titanium carbides are employed as components of hard alloys for cutting tools; calcium carbide, CaC_2 , is a source of acetylene; silicon carbide, SiC (carborundum), is used in the manufacture of grinding wheels etc.; iron carbide, FeC_3 (cementite), is a component of pig iron and steel.

carboanhydrase. An enzyme catalyzing the formation and decomposition of carbonic acid, only occurs in animal tissue, serves to remove CO_2 produced in tissue respiration.

carbocyclic compounds. A class of organic compounds whose molecules contain rings of carbon atoms; unlike heterocyclic compounds do not contain other than carbon atoms in rings. Are divided into saturated alicyclic (cycloparaffins), unsaturated, and aromatic compounds:



Include dyes, pharmaceuticals, many substances used as starting materials in the manufacture of synthetic resins and plastics.

carbohydrase. Any of enzymes catalyzing hydrolysis and synthesis of carbohydrates. Occurs in digestive juice, in cells of animals, plants, and microorganisms.

carbohydrate. An organic compound of the composition $\text{C}_n(\text{H}_2\text{O})_m$. Carbohydrates make up an important class of substances widely distributed in nature. Their structures correspond to aldehydo- or ketoalcohols. Simple carbohydrates or monosaccharides include glucose, fructose, etc. Complex carbohydrates or polysaccharides are usually divided into low-molecular-weight carbohydrates or disaccharides, e.g. saccharose, lactose, and high-molecular-weight compounds such as starch, cellulose, glycogen. Monosaccharides do not undergo hydrolysis; polysaccharides can be hydrolyzed to two (disaccharides) or more

(starch, cellulose) monosaccharide molecules. Carbohydrates play an important part in metabolism being the main source of energy. They are food products (saccharose, starch), used in the chemical industry, in the manufacture of ethanol, as starting materials for the production of fabrics and paper.

carbolic acid. See *phenol*.

carbon [L *carbo*, *carbonis*, coal] C. A Group IV element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 6, atomic mass 12.01115, contains two stable isotopes, ^{12}C (98.9%) and ^{13}C (1.1%). In 1961, 1/12 of the mass of an atom of ^{12}C was adopted as the unified atomic mass unit by the International Union of Pure and Applied Physics and the International Union of Pure and Applied Chemistry.

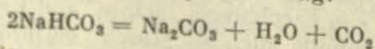
Properties: exists as several allotropic forms, e.g. diamond, graphite. The oxidation states in compounds +4 and, less frequently, +2 and +3. Unreactive under usual conditions, but shows a high reactivity at elevated temperatures, especially in the amorphous state. The chemistry of carbon has been developed into a separate branch of study, the organic chemistry.

Occurrence: carbon compounds are the major constituents of all organic substances and the products of their decomposition.

Uses: as an alloying element (steel, pig iron), as a material for electrodes, crucibles, in the manufacture of gunpowder, in smelting metals from their ores (coke), as an adsorbent (activated carbon), in the chemical industry. The ^{14}C isotope is used as a radioactive tracer.

carbon activated. See *activated carbon*.

carbonate. A salt or ester of carbonic acid, H_2CO_3 . Salts can be neutral and contain the CO_3^{2-} anion and acid (contain HCO_3^-). Alkali metal, ammonium, and thallium neutral carbonates are only soluble; their solutions are basic because of the hydrolysis. Calcium, barium, strontium, and lead neutral carbonates have very low solubilities; all acid metal carbonates are soluble in water. Acid carbonates give neutral salts upon heating:



Neutral carbonates are widely distributed in nature, e.g. calcite, CaCO_3 , magnesite, MgCO_3 , siderite, FeCO_3 ,

witherite, BaCO_3 , etc. Calcium, magnesium, barium, etc. carbonates are used in building, in the chemical industry, in optics, etc. Soda (Na_2CO_3 and NaHCO_3) is extensively used in industry and household. Acid carbonates play an important role being buffer substances maintaining blood's pH at a constant level. See also *soda*.

carbon black. An amorphous form of carbon, the product of incomplete combustion or thermal destruction of hydrocarbons. An excellent filler for rubber. Used in large amounts as a black pigment in polygraphy, in the manufacture of lacquers and dyes. Finely divided forms of amorphous silicon dioxide are used as a white substitute for carbon black; they are manufactured by the reaction of gaseous silicon tetrachloride with water vapour, and used as fillers for rubber, especially silicone rubber, in the manufacture of various lubricants, dyes, and lacquers.

carbon dioxide (carbon(IV) oxide) CO_2 .

Properties: a colourless gas, heavier than air, can be liquefied at 6×10^6 Pa. Strong cooling of CO_2 transforms it to a snow-like solid (dry ice). Dissolves in water. Carbon dioxide is a stable compound, combines with water to give carbonic acid, H_2CO_3 . Vigorously reacts with strong bases to form carbonates.

Occurrence: constitutes 0.03 to 0.04% of the atmosphere. A product of metabolism in organisms. Plays an important part in photosynthesis.

Derivation: by the calcination of limestone (in industry), by the action of HCl on CaCO_3 (in laboratory).

Uses: in the food industry (the manufacture of sugar, beer, beverages, etc.), as a refrigerant (dry ice), in the chemical industry (the manufacture of soda, urea, as an inert medium).

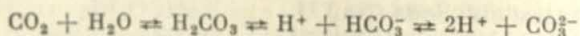
carbon disulphide CS_2 . A compound of sulphur and carbon.

Properties: a colourless liquid with a disagreeable odour. In part decomposes in the light. Poisonous, inflammable.

A good solvent for fats, oils, resins, and rubber; dissolves sulphur, phosphorus, iodine, and silver nitrate.

Uses: about 80% of all carbon disulphide manufactured is used in the production of viscose rayon; also used in the manufacture of various substances (xanthates, carbon tetrachloride, thiocyanates), as an extractant, in the vulcanization of rubber.

carbonic acid H_2CO_3 . A weak dibasic acid formed in the dissolution of CO_2 in water:



Forms neutral (carbonates) and acid (hydrocarbonates) salts. See *carbon dioxide*.

carbon monoxide (carbon(II) oxide) CO . The product of incomplete oxidation of carbon, a colourless, tasteless, and odourless gas, slightly soluble in water. Poisonous. Has important industrial applications as a fuel (air gas, illuminating gas) and a reducing agent. Together with hydrogen, a starting material for the synthesis of methanol.

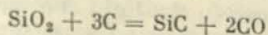
carbon tetrachloride (tetrachloromethane*) CCl_4 . A colourless heavy liquid with a chloroform-like odour, not flammable. Used as a solvent for fats, resins, rubber, in the manufacture of Freons, as an extractant, in medicine.

carbonyl chloride (phosgene) COCl_2 . A colourless gas with an odour of rotten hay; a liquid at temperatures below $+8^\circ\text{C}$. Heavier than air in the gaseous state. Made by heating a mixture of CO and Cl_2 in the presence of carbon. Very poisonous. A war gas (a lung irritant), was used in the World War I. Employed in the manufacture of various dyes.

carbonyl group $\text{C}=\text{O}$. Contained in ketones.

carbonyls of metals. Chemical compounds of carbon monoxide, CO , and metals, e.g. iron carbonyl, $\text{Fe}(\text{CO})_5$. Thermally unstable substances. Used in the preparation of some pure metals.

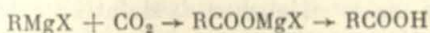
Carborundum. Trademark for abrasives and refractories of silicon carbide, fused alumina, and other materials. Silicon carbide is made by heating a mixture of sand and coal in a special electric furnace



Covalent bonds between the Si and C atoms are responsible for an exceedingly high hardness of SiC . Carborundum is used in the manufacture of grinding wheels, coated abrasive products, and heating elements in furnaces.

carboxylation. A direct introduction of the carboxyl (COOH) group into organic substances under the action of CO_2 .

The passage of CO_2 into a solution of an organomagnesium compound followed by the hydrolysis yields the corresponding carboxylic acid



The carboxylation plays an important part in some enzymatic reactions. Enzymes catalyzing carboxylation are called carboxylases.

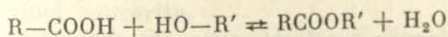
carboxyl group $\text{—C} \begin{array}{l} \text{O} \\ \text{OH} \end{array}$ (—COOH).

carboxylic acid. An organic substance containing the carboxyl group, $\text{—C} \begin{array}{l} \text{O} \\ \text{OH} \end{array}$. Depending on the radical attached

to that group carboxylic acids are classified as aliphatic (saturated and unsaturated), alicyclic, aromatic, and heterocyclic. Carboxylic acids may be mono-, di-, and polybasic (contain one, two, or more carboxyl groups). The introduction of other functional groups into carboxylic acids (e.g. —OH , =CO , or —NH_2) results in the formation of hydroxy-, keto-, amino, etc. acids. Carboxylic acids are weak acids, can displace carbonic acid from solutions of metal carbonates. The hydroxyl function of

the $\text{—C} \begin{array}{l} \text{O} \\ \text{OH} \end{array}$ group can be replaced by other groups.

The interaction of carboxylic acids and alcohols yields esters (the esterification reaction):



Carboxylic acids are prepared by the oxidation of aldehydes and ketones. They occur in nature in the free state or in the form of their derivatives; found in fats, essential oils, blood, fruits.

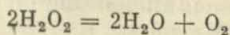
carnallite. A double salt of potassium and magnesium chlorides, $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$, a mineral. Used in the manufacture of magnesium, potassium salts.

carotene [*L. carota*, carrot]. A yellow-orange pigment, an unsaturated hydrocarbon of the composition $\text{C}_{40}\text{H}_{56}$. Insoluble in water but dissolves in organic solvents. Contained in leaves of all plants, in carrot roots, wild rose fruits, etc. A precursor of vitamin A.

carriers in chemistry. Substances (macrocomponents) that capture other substances (microcomponents) in various chemical processes such as precipitation. Used for concentrating traces of elements, isolating microquantities of radioactive isotopes.

casein [*L. caseus*, cheese]. A complex protein, a phospho-protein, the major protein component of milk. Practically insoluble in water and organic solvents, dissolves in aqueous solutions of salts and alkalis. An important food product, a component of curds and cheese. Used in the manufacture of plastics, adhesives, synthetic fibre.

catalase. An enzyme catalyzing the decomposition of hydrogen peroxide to water and molecular oxygen:



Found almost in all organisms, protects from harmful action of hydrogen peroxide formed in biological oxidation processes (e.g. in respiration).

catalysis [*Gk katalysis*, dissolution]. A change of a reaction rate in the presence of a catalyst. Catalysts may speed up the reaction or slow it down to almost complete suppression. The phenomenon is often observed in nature and widely employed in industry (in the manufacture of sulphuric acid, ammonia, nitric acid, etc.).

catalyst poison. A substance causing "poisoning" of a catalyst, i.e. a decrease of its catalytic action or its complete deactivation. Poisoning is caused by the adsorption of the substance on the surface of a catalyst. The commonest catalyst poisons are H_2O , CO , CO_2 , H_2S , N , P , As , and Sb .

catalysts. Compounds affecting the rate of a chemical reaction. Can form intermediates with the reactants but are absent from the final products. The most familiar catalysts are metals (Pt , Pd , Ni , Co , Fe), oxides (V_2O_5 , MnO_2 , Cr_2O_3 , NiO), and sulphides (MoS_2 , WS_2 , CoS).

cathode [*Gk kathodos*, going down]. An electrode connected to the negative pole of a constant current source.

cation. A positively charged ion, e.g. H^+ , H_3O^+ , Na^+ , NH_4^+ .

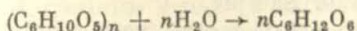
cation exchanger. See *ion exchanger*.

caustic alkalis. The hydroxides LiOH , NaOH , KOH , RbOH , and CsOH . The strongest bases; white, highly deliquescent solids. Their dissolution in water is accompanied by release of much heat. Aqueous solutions are strongly basic.

caustic soda. See *sodium hydroxide*.

celestine. A mineral, SrSO_4 . Colour white or bluish. Used in pyrotechniques, chemistry, and medicine.

cellulose (from cell). A high-molecular-weight carbohydrate (a polysaccharide), the major component of plant cell walls. Incorporates glucose residues and yields glucose when subjected to acid hydrolysis:



Cotton used in the manufacture of fabrics is almost pure cellulose. Paper is made from cellulose of wood. Cellulose and its esters are used in the manufacture of synthetic fibre (rayon from the viscose, acetate, cuprammonium processes), plastics, photographic film, lacquers, smokeless gunpowder, etc. See *acetyl cellulose*, *nitrocellulose*.

cementation of steel. A process in which the surface of an object made of low-carbon steel is saturated with carbon to increase its hardness and wearability.

cementite. Iron carbide, Fe_3C . Contained in iron-carbon alloys. Very hard and brittle.

centrifuging. The separation of heterogeneous systems (e.g. liquid—solid particles) into fractions of different densities based on the use of centrifugal force. Carried out in centrifuges. Employed to separate precipitates from solutions, to isolate impure liquids. Can also be applied to emulsions, e.g. the separation of milk. High-molecular-weight substances and biological systems are studied using ultracentrifuges. Centrifuging is employed in the chemical, food, and petroleum industries.

ceresin. Purified ozocerite.

cerium [named after the asteroid Ceres] Ce. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 58, atomic mass 140.12. Discovered in 1803 (two years after the asteroid) by Klaproth and, independently, Berzelius and Hisinger. The most abundant and extensively used lanthanide.

Properties: a soft grey metal, reactive. The oxidation states in compounds +3 and +4.

Occurrence: the chief ore is monazite.

Uses: in the manufacture of special alloys possessing high ductility and resistance to heating, glasses that do not undergo darkening under radioactive irradiation, arc electrodes, pyrophoric alloys, ignition devices. Ceri-

um(IV) salts are strong oxidizing agents used in titrimetric determinations of various reducing agents.

cesium [*L caesius*, bluish-grey] Cs. A Group I element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 55, atomic mass 132.905. Contains one stable isotope, ^{133}Cs . Discovered by Bunzen and Kirchhoff in 1860 who observed its blue line in the spectrum of a mineral water sample.

Properties: an alkali metal, very reactive, pyrophoric, decomposes water, reacts violently with other substances. The oxidation state in compounds +1.

Occurrence: in the mineral lepidolite.

Derivation: as a by-product of lithium manufacture.

Uses: photocells.

cetane. See *hexadecane*.

chain reaction. A chemical or a nuclear reaction where the appearance of an active particle (a free radical or an atom in chemical reactions, a neutron in nuclear reactions) causes a sequence (chain) of consecutive transformations of inactive molecules or nuclei. Unlike molecules free radicals and atoms have free valences facilitating their interactions with initial molecules. Any collision of a free radical (R^\bullet) with a molecule results in the cleavage of one of the valence bonds of the latter; a new chemical bond and a new free radical are thus formed. The newly formed radical reacts with one more molecule, and the chain propagates. In nuclear chain reactions, the role of active particles is played by neutrons which are not charged and therefore freely collide with atomic nuclei causing nuclear reactions (fission). Examples of chemical chain reactions are oxidation processes (combustion, explosion), cracking, polymerization, and other reactions frequently used in the chemical and petroleum industries. The study of nuclear chain reactions is essential to the utilization of nuclear energy.

chalcedony. A semitransparent mineral, a fibrous variety of quartz. Hardness 6.5 to 7. Colour variable: reddish (cornelian), greenish (chrysoprase). Used as an abrasive and a gem stone. A variety with thin streaks is called agate.

chalcocite (copper glance). A sulphide mineral, Cu_2S . Colour lead-grey or black, an ore of copper.

chalcopyrite (copper pyrites, yellow copper). A mineral, CuFeS_2 . Colour gold-yellow. The chief ore of copper.

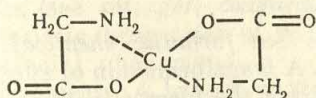
chalk. A white rock, almost pure (often up to 99%) calcium carbonate. Used in the manufacture of lacquers and dyes (a white pigment), in the rubber and paper industries, for writing, in the manufacture of sugar (the purification of beet juice), binding materials (lime, Portland cement), glass.

charcoal, animal (bone charcoal). Made by carbonizing degreased bones, contains 7 to 11% carbon, about 8% calcium phosphate, and other inorganic salts. Shows a very high adsorption power.

charcoal. A solid porous high-carbon product, made by heating wood in the absence of air. Used in metallurgy, smithery, in the manufacture of gunpowder, and also for absorbing gases and vapours.

charge. A mixture of raw materials ment for processing in the chemical industry or metallurgy. Thus a mixture of an ore, a flux, and coke for smelting pig iron is a charge for a blast furnace.

chelate compounds [Gk *chele*, a claw]. Cyclic coordination compounds formed in the interaction of metal ions with some organic substances containing salt-forming and coordination groups. An example is the chelate compound of copper and glycocoll:



Chelate compounds contain the central ion (particle) and the *ligands* attracted by coordinate links to that particle. Chelate compounds are used in chemistry to separate, concentrate, and determine various elements.

chelating agents in analytical chemistry. Substances capable of forming chelate compounds of definite compositions, in particular, amino polycarboxylic acids with several $-\text{CH}_2-\text{COOH}$ groups attached to the same nitrogen atom. The carboxyl groups can form several coordination bonds with a central ion to give stable water-soluble complexes with most metals. See also *ethylenediaminetetracetic acid*.

chelatology. A titrimetric technique utilizing the ability of some organic ligands to chelate the ions present in a

solution at a sufficiently high rate. The most familiar example is the titration with ethylenediaminetetracetic acid and its analogues (amino polycarboxylic acids) which react with most metal ions practically instantaneously to give stable water-soluble compounds of a constant composition. Amino polycarboxylic acids can be used for titrimetric determination of practically all cations and many anions. See *disodium edetate, complexing techniques in analysis*.

chemical bond arises because the electrons of two separate atoms (atomic groups) are shared by both atoms (groups). Forces responsible for the formation of chemical bonds are of electric origin. The two most important types of chemical bond are ionic or electrovalent and covalent or homopolar bonds. Bonds of intermediate types are called semipolar. Donor-acceptor or coordination bonds closely resemble covalent bonds.

chemical current sources. Devices in which chemical energy is transformed directly into electric energy such as galvanic cells, storage batteries, and fuel cells.

chemical equation. An expression in which chemical formulas and numerical coefficients are used to represent a chemical reaction in conformity to the law of the conservation of mass; used to carry out necessary calculations for a given process.

chemical formula. See *formula, chemical*.

chemical reaction. A transformation of substances into other ones differing from the former in their compositions and properties; described by chemical equations. Unlike nuclear reactions chemical reactions do not cause transformations of atoms but only affect their states. There are several types of chemical reaction: combination, $2\text{Cu} + \text{O}_2 = 2\text{CuO}$; decomposition, $2\text{HgO} = 2\text{Hg} + \text{O}_2$; substitution, $\text{Fe} + \text{CuSO}_4 = \text{FeSO}_4 + \text{Cu}$; exchange, $\text{NaCl} + \text{H}_2\text{SO}_4 = \text{HCl} + \text{NaHSO}_4$.

chemical symbols. See *symbols of chemical elements*.

chemical technology. A branch of chemistry intended to develop effective and economical procedures for utilizing natural materials by chemical means. Divided into inorganic synthesis (the manufacture of acids, alkalis, soda, silicate materials, inorganic fertilizers, salts, etc.) and organic synthesis (the manufacture of synthetic rubber, plastics, dyes, alcohols, organic acids, etc.). In a looser

sense, it also includes the chemical processing of coals, petroleum, gas, and wood.

chemiluminescence. A luminescence caused by a chemical action, e.g. luminescence of phosphorus caused by slow oxidation. Chemiluminescence accompanies exothermic chemical processes. Chemiluminescence in living organisms (luminescence of insects, worms, or fish) is called bioluminescence and is caused by oxidation processes. See *luminescence*.

chemisorption. A sorption process in which sorbed and sorbent particles chemically interact with each other. *

chemistry. A science studying chemical elements and their compounds (their composition, properties, and structure), and interconversions of substances (chemical reactions). Chemistry is divided into the inorganic, organic, physical, and analytical chemistry. Chemistry is involved with other sciences, and on its borders, such branches of study as biochemistry, geochemistry, etc. have been developed. The progress in chemistry has led to a rapid growth of the chemical industry which plays an important part in the development of all fields of industry.

chemistry of colloids [Gk *kolla*, glue]. A branch of chemical science dealing with the formation and disintegration of disperse systems (see *sol*, *gel*, *coagulation*, *peptization*), and the characteristic properties of such systems associated with interfacial phenomena.

chemistry of cosmic objects. A branch of study dealing with the chemical and isotopic composition of cosmic objects and interstellar medium. Studies the chemical elements constituting cosmic objects, the processes of radioactive decay and nuclear reactions, etc. The same elements as those occurring on earth were found to be distributed in the cosmos.

chemistry of nuclear fuel. A branch of chemistry studying the properties of fissionable materials and the techniques of their manufacture (thorium, Th; uranium, U; plutonium, Pu). See also *nuclear fuel*.

chemistry of plasma. A branch of chemistry studying chemical processes in low-temperature, 10^3 to 2×10^4 K, plasma at pressures of 10^{-1} to 10^9 Pa, patterns of reactions in plasma, and principles of plasmachemical engineering. Dates from 1960s.

chemistry of wood. A branch of chemical science dealing with processes for the manufacture of various chemical products such as spirits of turpentine, rosin, acetic acid from wood.

chemithrapy. Treatment of infectious diseases with the help of chemical substances, e.g. sulphanilamides.

chemosynthesis. A biological process of the formation of organic substances from inorganic ones, with energy required for reduction processes supplies by the oxidation of ammonia, hydrogen sulphide, etc. Performed by some microorganisms.

chloramphenicol. An antibiotic, a colourless crystalline solid with a very bitter taste. The first antibiotic to be prepared synthetically. Used in treatment of typhoid fever, dysentery, and other diseases. Almost nontoxic.

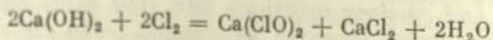
chlorate. A metal salt of chloric acid, HClO_3 .

chloric acid HClO_3 ($\text{HO}-\text{Cl} \begin{smallmatrix} \text{O} \\ \diagup \\ \diagdown \\ \text{O} \end{smallmatrix}$). A strong monobasic acid,

exists only in aqueous solutions. Chloric acid salts, chlorates, are strong oxidizing agents; their mixtures with substances that can act as reducing agents are dangerously explosive. Potassium chlorate (Berthollet's salt), KClO_3 , is used in the manufacture of matches, sodium chlorate, NaClO_3 , as a weed killer.

chloride. A compound of chlorine and a metal, a salt of hydrochloric acid.

chlorinated lime (chloride of lime, bleaching powder). A mixture of calcium hypochlorite and calcium chloride, a white powder with an odour of chlorine. Made by the action of chlorine on dry slaked lime:

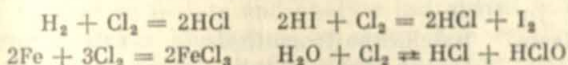


Used as an oxidizing agent, in the textile and paper industries, in the chemical industry, as a disinfectant.

chlorination. The introduction of chlorine into molecules of inorganic and organic substances, widely used in the chemical industry.

chlorine [Gk *chloros*, pale green] Cl. A Group VII element of the 3rd period of the Mendeleev Periodic Table of Elements, atomic number 17, atomic mass 35.453, contains two stable isotopes, ^{35}Cl and ^{37}Cl . A halogen. Discovered in 1774 by Scheele.

Properties: a greenish-yellow gas (hence its name) with an irritating and suffocating odour, easy to liquefy, poisonous. Chlorine is 2.5 times heavier than air. Reactive, the oxidation states in compounds range from -1 to $+7$:

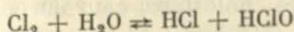


Several compounds of chlorine and oxygen are known; all of them are unstable.

Occurrence: occurs in a number of minerals, e.g. halite (rock salt), NaCl ; sylvite, KCl ; sylvinite, $\text{KCl} \cdot \text{NaCl}$, carnalite, $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$; etc. Found in sea water. **Derivation:** by the electrolysis of solutions of sodium chloride.

Uses: extensively used in the manufacture of various inorganic substances (HCl , metal chlorides, chlorinated lime, metal hypochlorites, etc.), chlorinated organic compounds (dyes, pharmaceuticals, pesticides, solvents), for bleaching fabrics, paper, cellulose, for disinfection of water, etc.

chlorine water. A solution of chlorine in water; the dissolution is accompanied by the reaction:



chloroacetophenone (phenacylchloride, phenylchloromethylketone) $\text{C}_6\text{H}_5\text{COCH}_2\text{Cl}$. A white crystalline solid. Commercial products may be yellowish crystals with a floral odour. One of the strongest tear gases.

chlorobenzene $\text{C}_6\text{H}_5\text{Cl}$. The product of the chlorination of benzene, used in the manufacture of DDT, dinitrophenol, and as a solvent.

chloroform (trichloromethane*) CHCl_3 .

Properties: a heavy colourless liquid with a characteristic sweet odour, insoluble in water, miscible with ethanol and ether. Not flammable. In the light undergoes oxidation by air oxygen to give phosgene (carbonyl chloride), COCl_2 , and hydrogen chloride, HCl .

Derivation: by the chlorination of methane.

Uses: earlier used in medicine as a narcotic, now replaced by less toxic substances. Used as a solvent of rubber, resins, fats, etc., as an extractant in the analytical chemistry, in the manufacture of Freon.

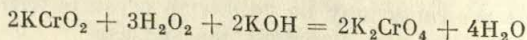
chlorophyll [Gk *chloros*, green + *phyllon*, a leaf]. A green pigment of plants; plays a very important part in plant life: it participates in photosynthesis. Has the structure of a complex chelate organomagnesium compound resembling that of blood haemoglobin. Synthesized by Woodward in 1960.

chloropierin (trichloronitromethane*, nitrochloroform) Cl_3CNO_2 . A liquid with a peculiar sharp odour. Made by the action of chlorinated lime on picric acid. A lachrymator, in large concentrations causes suffocation; was used as a war gas in the World War I. Employed as an insecticide.

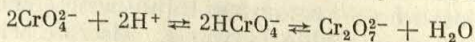
chlorpromazine. A pharmaceutical, has a general toxic action, suppresses metabolic processes, especially those of the central nervous system, has a sedative, antispasmodic, antiemetic action, decreases temperature and arterial blood pressure.

cholesterol. A monohydric polycyclic alcohol of the sterol series, occurs in animals in the free state and in the form of esters with the higher fatty acids. Large amounts of cholesterol are found in nerve tissue, skin fat, and bile. Many substances important for organisms are cholesterol derivatives (vitamins, sex hormones, etc.). Disturbances of metabolism of cholesterol cause atherosclerosis, cholecystitis, etc.

chromate. A metal salt of chromic acid, H_2CrO_4 . Made by the oxidation of chromium(III):



The reaction is accompanied by a change in solution colouration from green to yellow characteristic of the CrO_4^{2-} ion. In acid solutions the chromate ion is transformed into the dichromate ion having an orange colour:



Metal chromates are used as strong oxidizing agents and as pigments. Lead chromate, PbCrO_4 , is a bright-yellow compound, slightly soluble in water; used as a yellow oil-colour pigment (chrome yellow). See *dichromates*.

chromatography. A method for separating and analysing mixtures of substances based on differences in sorption of the mixture components by a given sorbent. First suggested (1903) by Tswett. The separation is carried out

in columns filled with silica gel, alumina, ion exchangers, etc., or on special paper. Because of different sorption of mixture components (the mobile phase) they are separated into zones along the column packed with a sorbent (the stationary phase) to produce a chromatogram which can be used to isolate and analyse individual substances (the process is analogous to many-step rectification). Depending on the state of aggregation of the sample (mobile phase) chromatography may be gas and liquid; depending on the separation mechanism the chromatographing techniques are classified as ion exchanging, precipitation, partition, and molecular (adsorption). Lastly, chromatographing can be carried out on columns (column chromatography), special porous paper (paper chromatography), in capillaries (capillary chromatography), and thin sorbent layers (thin layer chromatography). Chromatographing is applied to analyse mixtures of inorganic and organic substances, to concentrate traces of elements. In the chemical industry, it is used in the purification and separation of substances. It provides a means for analysing mixtures of substances having related properties (e.g. lanthanides, actinides, isotope mixtures, mixtures of amino acids, hydrocarbons).

Chromel. Tradename for a series of nickel-chromium alloys; used, e.g. in pyrometry as a material for thermocouples.

chrome plating. A coating of metals and various articles with chromium to prevent corrosion.

chromic acid mixture. A solution of potassium or sodium dichromate in concentrated H_2SO_4 . A strong oxidizing agent. Used to oxidize organic substances, to wash laboratory ware.

chromium [Gk *chroma*, a colour] Cr. A Group VI element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 24, atomic mass 51.996. Discovered in 1797 by Vauquelin.

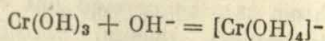
Properties: a steel-grey metal, very hard, high-melting, unreactive; unattacked by moisture and air oxygen at room temperature. The oxidation states in compounds are +2 (unstable), +3, +6. Reacts with dilute acids; HNO_3 passivates chromium.

Occurrence: the chief ore is chromite (chrome iron ore), $\text{FeCr}_2\text{O}_4(\text{FeO} \cdot \text{Cr}_2\text{O}_3)$.

Derivation: by the reduction of Cr_2O_3 with aluminium or

silicon; very pure chromium is obtained electrolytically. Uses: as an alloying element (steel, various alloys), for chrome plating of metal articles (to increase their hardness, resistance to thermal and chemical actions, for decorative purposes). Chromium and its compounds are used in the ceramic, chemical, and glass industries, in powder metallurgy, etc. See also *chromium compounds*.

chromium compounds. Chromic oxide (chrome(III) oxide), Cr_2O_3 , is a high-melting substance with a green colour, used as glue and oil paint pigment ("chrome green"). Chromic hydroxide, $\text{Cr}(\text{OH})_3$, is amphoteric, it dissolves in excess alkalis to give chromites:



e.g. sodium chromite, $\text{Na}[\text{Cr}(\text{OH})_4]$. Fusing of Cr_2O_3 with other metal oxides yields chromites of the composition $\text{Me}^{\text{II}}(\text{CrO}_2)_2$. An important compound containing chromium(III) is chromium potassium alum, $\text{KCr}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$, blue-violet crystals used in the textile industry and in the manufacture of leather. Chromium trioxide, CrO_3 , contains chromium(VI). It is a strong oxidizing agent, gives two acids existing in aqueous solutions, chromic acid, H_2CrO_4 , and dichromic acid, $\text{H}_2\text{Cr}_2\text{O}_7$. The corresponding salts, metal chromates and dichromates, are strong oxidants.

chromophore [Gk *chroma*, a colour + *pherein*, to bear]. An unsaturated atomic grouping causing the appearance of colouration. The chromophore theory of colour was developed by Witt in 1878. The most familiar chromophores are the azo group, $-\text{N} \equiv \text{N}-$, the nitro group, $-\text{NO}_2$, the nitroso group, $-\text{NO}$, and the carbonyl group, $>\text{CO}$.

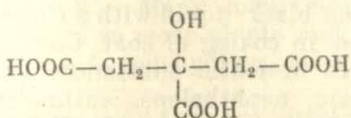
The introduction of other groups called auxochromes (from Gk *auxanien*, to increase) such as $-\text{OH}$, or $-\text{NH}_2$ deepens colours.

chrysoberyl. A mineral, beryllium aluminate BeAl_2O_4 . Used as an ore of beryllium; transparent varieties, e.g. alexandrite, are gem stones.

cinnabar. A mineral, mercuric sulphide HgS . See *mercury*.

cinnamic acid (beta-phenylacrylic acid) $\text{C}_6\text{H}_5\text{CH}=\text{CHCOOH}$. Used in syntheses of esters, in perfumery, in the manufacture of some pharmaceuticals, and in the analytical chemistry.

citrate. A salt or ester of citric acid.
citric acid



A crystalline substance, very soluble in water. A typical polybasic acid. Found in some fruits (lemon, lime, pineapple, etc.). Used in the manufacture of pharmaceuticals, in the food industry. Citric acid and its salts, metal citrates, are extensively used in the analytical chemistry for masking, employed for the separation of lanthanides.

clay. A sedimentary rock, plastic and can be given a desired shape when wet; retains that shape upon drying and becomes stonehard after it has been calcined. The major proportion of any clay is comprised by kaolinite and like minerals. Clays usually contain other minerals including quartz, opal, mica, hydroxides of iron and aluminium, and organic admixtures. Various varieties of clay are used in the manufacture of cement, bricks, and tile. Kaolin or China clay is used in the manufacture of porcelain, whiteware, etc.

cleavability (in crystallography). The property of crystals to be cleaved along certain axes to give plane smooth surfaces.

coacervation [L *acervare*, to heap up]. A demixing of a colloidal system with the formation of aggregates (coacervates) visible as two liquid layers or drops. May result from a partial dehydration of the disperse phase of a colloidal system being the initial coagulation step. According to Oparin coacervation played an important role in the appearance of life on earth.

coagulation [L *coagulare*, to cause a fluid to curdle]. The aggregation of small particles of disperse systems to larger ones under the action of adhesion forces; results in the separation of a flaky precipitate from a colloidal system or the formation of a gel.

coal, bituminous. A solid fossil fuel of the plant origin, colour black or black-grey. Contains 75 to 97 % carbon. Used as a fuel and as a raw material in the chemical industry.

coal, fossil. A general term for solid fuels of the plant origin such as peat, lignite, bituminous coal, anthracite.

coal tar. A viscous black liquid with a characteristic phenol odour, formed in coking of coal. Coal tar is a complex mixture where aromatic substances such as benzene, toluene, xylene, naphthalene, anthracene, and phenol predominate; used as a raw material for their manufacture. Also used in building, paving, and as a fuel.

cobalt [Gk *kobold*, a demon of the mines]. A Group VIII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 27, atomic mass 58.9332. Natural cobalt contains one stable isotope, ^{59}Co . Discovered by Brandt in 1735.

Properties: a solid with a metallic glitter and blue cast, ductile and malleable. Compact metal is not oxidized in the air; at 300 °C, a thin coating of cobalt oxide is formed on its surface. Slowly dissolves in dilute HCl, H_2SO_4 , and HNO_3 . The oxidation states in compounds +2, +3. Halogens react with cobalt even at room temperature. Forms basic oxides of the compositions CoO , Co_2O_3 , and Co_3O_4 . Cobalt forms various complex ions, e.g. $[\text{Co}(\text{NH}_3)_6]^{3+}$, $[\text{Co}(\text{NH}_3)_5\text{H}_2\text{O}]^{3+}$, $[\text{Co}(\text{NO}_2)_6]^{3-}$, and numerous coordination compounds.

Occurrence: a scattered element, found in many igneous rocks, sea water, mineral springs. Cobalt minerals are known (e.g. cobaltite). Found in soil, in plants and animals, occurs as admixtures in ores of copper, nickel, and some other metals.

Uses: in the manufacture of various special alloys and steels, as a catalyst, in agriculture (a microfertilizer). The ^{60}Co radioactive isotope is widely used as a source of gamma-radiation in the radiation chemistry, medicine, radiography, for thickness and density measurements. Cobalt is essential to man. Cobalt compounds are used in the manufacture of pigments and enamels.

cocaine. An alkaloid extracted from leaves of *Erythroxylon coca*; slightly soluble in water, soluble in organic solvents. Used as a local anaesthetic in medicine. A narcotic.

codeine (methylmorphine). One of the alkaloids extracted from opium contained in the juice of *Papaver somniferum* L., a white crystalline powder whose physiological action is similar to that of morphine.

coenzyme. An organic substance of a non-protein nature, together with a protein called protein carrier makes up an enzyme molecule. Many coenzymes are derivatives of vitamins. Found in most plants and animals. Examples are coenzyme A, codehydrase, cocarboxylase, and the adenyl system.

cohesion [L *cohaerere*, *co-*, together + *haerere*, to stick]. A sticking together of atoms, ions, or molecules in the bulk of a given body. Cohesion forces in solids far exceed those in liquids which in their turn are larger than cohesion forces in gases. See *adhesion*.

coke. A solid residue formed in heating various fuels to high temperatures in the absence of air. Coke can be made from coal, pitch, and petroleum. Coal coke is a sintered solid formed by heating certain kinds of coal in coke ovens to 900-1050 °C. Used in blast furnaces. Coke from pitch is a solid residue from the decomposition of coal pitch, contains much carbon. Used in the manufacture of electrodes. Petroleum coke is a solid product of destructive distillation of petroleum materials.

coke-oven gas (coal gas; bench gas). A mixture of gases produced by coking fossil coals. Contains methane, hydrogen, carbon monoxide, and non-combustible admixtures such as CO₂, NH₃, and N₂. A fuel of high heating power. Ammonia contained in coke-oven gas is collected in the form of ammonium sulphate, a nitrogen fertilizer.

coking. The industrial process for making coke, coke-oven gas, and coal tar by heating bituminous coal in special ovens to 900-1050 °C in the absence of oxygen.

collodion [Gk *kollodes*, glue-like]. A 4% solution of nitrocellulose in a 1:7 mixture of ethanol and ether. A colourless or pale yellow liquid, leaves a tight film after the solvent has been evaporated. Used in chemistry and medicine. Flammable.

colloidal solution. See *sol*.

colorimeter. An instrument for measuring colour intensity of a given solution by comparison with a standard.

colorimetry. An analytical technique based on the determination of the concentration of a substance from the intensity of solution colouration (more accurately, from the intensity of light absorption). The intensities are determined visually or with the help of colorimeters.

combustion. A fast chemical transformation accompanied by release of heat and emission of light, e.g. reactions of certain substances with oxygen. The term is applied to all fast chemical transformations such as decomposition of explosives, ozone, acetylene, combination of some substances with chlorine, fluorine, etc. Combustion is a complex reaction involving a large number of elementary redox events causing redistribution of valence electrons between atoms of reacting substances.

***pi*-complex.** A compound or a coordination compound where the chemical bonding between electron acceptors (metal cations, metal salts) and electron donors (unsaturated or aromatic compounds) involves *pi*-electrons of the donor. A large number of *pi*-complexes are known, e.g. *ferrocene*.

complex. See *coordination compound*.

complexing techniques in chemical analysis. The methods of quantitative titrimetric analysis based on various reactions of formation of coordination compounds, such as complexometric titration, formation of mercuric coordination compounds, fluoride complexes, etc. Methods based on the use of chelating agents are especially important.

composite fertilizers. Fertilizers containing several nutrition elements, e.g. ammophos, diamphos, potassium phosphates, magnesium ammonium phosphate, saltpetre, nitrophosphates, etc.

compound chemical. A chemically individual substance containing atoms of different elements. An important distinguishing feature of chemical compounds is their homogeneity and the constant composition.

concentrated solution. A solution with a high concentration of a solute.

concentration. A relative amount of a given component in a solution. The most familiar means of expressing the concentration are as follows. Concentration by mass is the ratio of the mass of a given component to the mass of the whole system; that ratio multiplied by 100 gives the per cent concentration by mass. The mole fraction is the ratio of the number of moles of a given component to the total number of moles; multiplied by 100 gives mole per cent. The concentration by volume is the ratio of the volume of a given component to the volume of the system as a whole; multiplied by 100 gives volume per cent. The concentration is often expressed in grams of a solute

(dissolved substance) per 100 g, sometimes 1 litre, of a solvent, or as the number of moles of a solute per 1000 moles of a solvent. The molar concentration (molarity) is the number of moles of a solute per 1 litre of a solution; molarity is the number of moles of a solute per 1000 g of a solvent. Normality is the form of expressing solution concentrations used in the titrimetric analysis.

concentration of hydrogen ions. See pH.

concentration of minerals. A group of processes for the removal of waste rock and the preparation of concentrates, i.e. products high in the desired components. The separation techniques may be based on different densities, magnetic properties, wetting (see flotation) of minerals and waste rock.

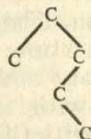
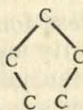
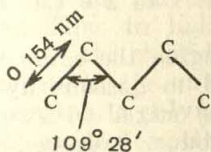
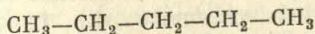
concrete [L *concrescere*, to grow together]. A material for building made by mixing cement, water, sand, gravel, and slag.

condensation (phase transition). The transition of a substance from the gas (vapour) state to the liquid or solid state.

condensation (reaction). The formation of large molecules from smaller ones with the elimination or transfer of atoms or atomic groups. Thus the condensation of phenol with formaldehyde yields phenol-formaldehyde resins. See also *polycondensation*.

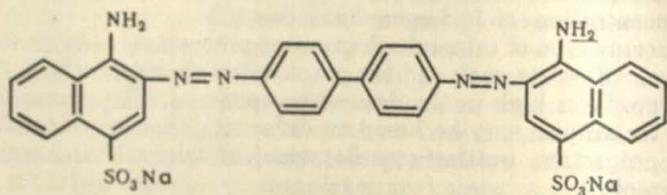
conductometry. An electrochemical method of analysis in which concentrations are determined from solution conductivities. Applied to solutions of salts, acids, bases, to monitor the composition of some industrial solutions.

conformation [L *conformare*, to fashion, form]. The arrangement of the parts of a molecule resulting from rotations of atoms or atomic groups (substituents) about single bonds with retention of the chemical structure, bond lengths and valence angles. Different conformations of the same molecule are called rotational isomers or conformers. Several planar pentane conformers may serve as an example:



congealing. A continuous increase in viscosity of colloids or high-molecular-weight compounds, results in solidification of the whole system into a homogeneous dense structure (a gel). Thus a solution of gelatin sets to a dense jelly if allowed to stand.

Congo red



An azo dye, made in the reaction of diazotized benzidine and naphthionic acid. Solutions of Congo red are red in neutral or weakly acid media (pH 5.2), blue in acid media (pH 3.0). Used as an indicator in the analytical chemistry.

conjugated bonds. Multiple (double or triple) bonds which alternate with single bonds; occur, e.g. in 1,3-butadiene, $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$, and acrylonitrile, $\text{CH}_2=\text{CH}-\text{C}\equiv\text{N}$.

conservation of mass, law of (Lomonosov, 1748; later Lavoisier). The total mass (weight) of the substances participating in a chemical reaction is equal to the total mass (weight) of the reaction products. One of the fundamental laws of chemistry.

consistent lubricant. A mixture of mineral oils and thickening agents such as salts of the higher fatty acids, paraffin, etc. Used to reduce friction in gears, chain drives, bearings, and as protecting coatings on metal surfaces.

constantan. An alloy with high thermal electromotive force, low thermal expansion, and constant electric resistance. Used in rheostats, thermocouples, heating devices. The composition is 39 to 41% Ni, 1 to 2% Co. The rest is copper.

conversion. The process for changing the composition of a gas mixture; usually applied to gaseous hydrocarbons (methane and its homologues) mixed with carbon monoxide with the purpose to produce hydrogen or its mixtures with CO. The resulting mixtures are used in the or-

ganic synthesis, as reducing agents in metallurgy, or subjected to further treatment in order to obtain pure hydrogen.

converter. A furnace for the manufacture of steel from molten pig iron by blasting air or air enriched in oxygen through the melt. See *Bessemer process*, *Thomas and Gilchrist process*.

coordination bond. See *donor-acceptor bond*.

coordination compound (Werner complex). A compound or a complex ion formed by the addition of neutral molecules or ions called ligands to a given ion or atom (the central ion). Unlike double salts coordination compounds dissociate in solutions only slightly; can contain a complex anion, e.g. $[\text{Fe}(\text{CN})_6]^{3-}$, a complex cation, e.g. $[\text{Ag}(\text{NH}_3)_2]^+$, or give no ions at all upon dissolution (nonelectrolyte-type compounds). Coordination compounds are numerous and varied. They are used in chemical analyses, in industry for the recovery of some metals from their ores (gold, silver, platinum family metals, etc.), for separating mixtures of elements (e.g. mixtures of lanthanides). They play an important role in plant and animal life; e.g. chlorophyll and haemoglobin are coordination compounds. See also *coordination theory*, *chelate compounds*.

coordination number. The total number of neutral molecules and ions attached to the central ion in a coordination compound; e.g. the coordination number of platinum is six (or platinum is six-coordinate) in $\text{K}_2[\text{PtCl}_6]$, copper is four-coordinate in $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$.

coordination theory. The theory of coordination compounds suggested by Werner in 1893. According to that theory, one of the ions (usually a positively charged ion) occupies the central position in any coordination compound (the central ion). In its nearest environment, a number of ions of the opposite charge or neutral molecules called ligands (addends) are arranged: these form the internal coordination layer (sphere). Other ions are farther from the central ion and form the outer coordination layer (sphere). Thus in $\text{K}_2[\text{PtCl}_6]$, the platinum ion is the central ion, the chloride ions are the ligands, and potassium occurs in the outer sphere.

copolymerization. A polymerizing together of two or several different monomers; the products (copolymers) contain two or more dissimilar units in their chains. Used to pre-

pare high-molecular-weight substances with intended properties.

copper [Gk *Kyprios*, Cyprus, where the best copper was produced] Cu. A Group I element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 29, atomic mass 63.546. Contains two stable isotopes, ^{63}Cu (69.1%) and ^{65}Cu (30.9%). Known to the ancients. Properties: a red (pink at fractures) metal, ductile and malleable; after silver, the best conductor of electricity and heat; unreactive, forms a superficial layer of green basic carbonate under the action of moist air. The oxidation states in compounds +1, +2, and, less frequently, +3. Easily combines with halogens, sulphur, and selenium, dissolves in HNO_3 , forms coordination compounds with ammonia, cyanides, etc. Copper salts are poisonous. Occurrence: sometimes native and also in the following minerals: chalcopyrite (copper pyrites), CuFeS_2 ; chalcocite (copper glance), Cu_2S ; malachite, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$; etc. Found in living organisms.

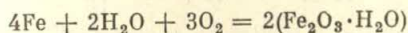
Uses: more than 50 per cent of all copper manufactured is used in electrical engineering (pure copper); copper alloys are also important materials (brass, bronze, German silver, etc.). Copper salts are used as pesticides in agriculture, as microfertilizers, catalysts, etc. See *copper compounds*.

copper compounds. The most important compounds of divalent copper are: cupric oxide, CuO , a black solid, used in the manufacture of glass and enamels, as an oxidizing agent in the organic analysis; cupric sulphate, crystallizes with five water molecules from aqueous solutions to form blue vitriol crystals, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, used in the manufacture of pigments, for impregnating wood, as a pesticide (Bordeaux mixture), in galvanic cells, and in medicine; basic cupric carbonates occur in nature as malachite, azurite. Compounds of univalent copper: cuprous chloride, Cu_2Cl_2 , used in the organic synthesis and gas analysis; cuprous and cupric sulphides (Cu_2S and CuS) are used for the pyrometallurgical preparation of copper, for the isolation of copper. All copper salts are poisonous; for that reason cooking utensils made of copper are subjected to tinplating.

coprecipitation. A capture of foreign substances (admixtures) by the precipitate of the major component. Results from

adsorption, occlusion, isomorphism, etc. Can cause serious errors in quantitative analysis. Used for concentrating admixtures prior to their determination.

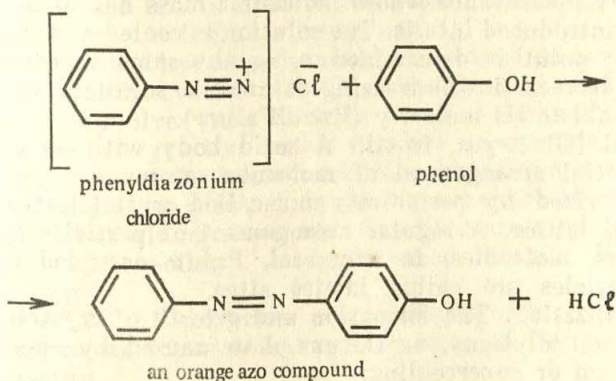
corrosion of metals [*L. corrodere*, to gnaw to pieces]. The destruction of metals under the action of medium with the oxidation of metal atoms to metal ions; rusting of iron is an example



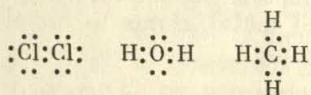
To prevent corrosion, metal surfaces are coated with oil colours, lacquers, enamels, or thin layers of other metals. An oxide film is formed on the surface of aluminium metal brought in contact with air oxygen: the film protects the metal from further corrosion. The rate of corrosion is especially high if two dissimilar metals such as iron and zinc or iron and tin touch each other and thus form a galvanic cell (electrochemical corrosion).

corundum Al_2O_3 . Natural aluminium oxide with minor admixtures of other elements determining its colouration. The purest transparent varieties are red ruby and blue sapphire. Corundum mixed with other minerals is called emery. Corundum is chemically stable, insoluble in acids, the hardest substance after diamond. Used as an abrasive. Corundum crystals can be grown artificially from aluminium oxide.

coupling. The combination of an aromatic amine, phenol, or some other substance with a diazonium compound (a diazonium ion) to give an azo compound, e.g.



The reaction was discovered in 1864 by Griss.
covalent bond. A bond formed by a pair of electrons,
 $A + B \rightarrow A : B$, each atom involved supplying one
 electron to the pair which is shared by both atoms, e.g.



Covalent bonds occur in molecules of simple gases (H_2 , Cl_2 , etc.) and compounds (e.g. H_2O , NH_3 , CH_4 , CO_2 , and HCl). See also *donor-acceptor bond*.

cracking. Thermal treatment of petroleum or heavy petroleum fractions at 400 to 500 °C; causes splitting of large hydrocarbon molecules and thus increases the fraction of low-boiling hydrocarbons, e.g. gasoline. Gives valuable materials for the synthesis of plastics, fibres, rubbers, washing substances, solvents, and other products.

cryolite [Gk *kryos*, cold + *lithos*, stone] Na_3AlF_6 . A mineral, colour greyish-white, occurs only rarely. Made artificially in large amounts from fluorspar, CaF_2 . Used in the electrolytic manufacture of aluminium and in the manufacture of milky-white glass, enamels, etc.

cryoscopy [Gk *kryos*, cold + *scopein*, to see]. A measuring of a decrease in the freezing point of a solution from the pure solvent for the determination of the molecular mass of a solute, suggested in 1882 by Raoult. First the freezing point of a certain amount of a pure solvent is determined. The solvent is then warmed up and a measured quantity of the substance whose molecular mass has to be found is introduced into it. The solution is cooled and its freezing point is determined using the same thermometer. A decrease in the freezing point of a solution is proportional to its molarity (Raoult's law).

crystal [Gk *kryos*, frost]. A solid body with an ordered spatial arrangement of molecules, atoms, or ions characterized by periodicity and called crystal lattice.

crystal lattice. A regular arrangement of particles (atoms, ions, molecules) in a crystal. Points occupied by the particles are called lattice sites.

crystallization. The formation and growth of crystals from melts, solutions, or the gas phase caused by supersaturation or supercooling.

crystallochemistry. A branch of chemical study dealing with the nature of chemical bonds in crystals. Its subject matter is the relationships between the structure of crystals and their compositions and the conditions of their formation, and between the atomic structure of crystals and their physicochemical properties. The atomic spacings in crystals are determined from X-ray diffraction patterns.

crystallography. The science of crystals, studies the laws of formation of crystals, their morphology and atomic structure, physical properties, and the interactions of crystals with the environment.

cupelling. An oxidative melting of lead alloys with gold or silver for isolating the precious metals in the pure form: lead and other non-noble metals are oxidized by air oxygen upon heating whereas gold and silver remain unchanged. See *test analysis*.

cuprite. A red ore of copper, Cu_2O , contains 88.8% copper.

curie. A measure of the activity of a radioactive substance; one curie corresponds to 3.7×10^{10} disintegrations per second. Named after Marie Curie. Derivative units: 1 millicurie = 10^{-3} curie, 1 microcurie = 10^{-6} curie.

curium (after Pierre and Marie Curie) **Cm.** A radioactive element of the atomic number 96, an actinide. Discovered in fission products in 1944 by Seaborg, James, Morgan, and Ghiorso (USA). The isotopes with the mass numbers of 238 to 250 are known. The oxidation states in compounds +3 and +4. The longest-lived isotope, ^{247}Cm , has the half life of 1.64×10^7 years. An analogue of gadolinium. A bright silvery metal.

cyanide. A salt of hydrocyanic acid, e.g. potassium cyanide, KCN, sodium cyanide, NaCN. Used in the extraction of gold and silver from their ores (one of the methods of hydrometallurgy: the metals dissolve in cyanide solutions because of the formation of complex salts, see *silver*), in electroplating (gilding), in the organic synthesis, sometimes for nitriding steel, etc. Cyanides are used in the analytical chemistry for separating metals. Highly poisonous.

cyanogen $(\text{CN})_2$. A colourless poisonous gas with a pungent odour; an analogue of halogens in some of its chemical properties.

cyclic hydrocarbons. Hydrocarbons with closed chains of carbon atoms, include alicyclic hydrocarbons (saturated), aromatic hydrocarbons (unsaturated), etc.

cyclonite (sym-trimethylene trinitramine, trinitrotrimethylene-triamine, RDX). An explosive, made by nitrating methenamine with concentrated HNO_3 . Used in detonators, artillery shells, and for blasting.

cycloparaffin. See *alicyclic hydrocarbons*.

D

daltonide (after J. Dalton). A compound that conforms to the laws of constant composition and multiple proportions. Cf. *berthollide*.

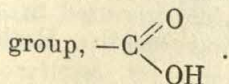
Dalton's laws. (i) The pressure of a mixture of gases which do not interact with each other chemically is equal to the sum of their partial pressures. The law holds with ideal gases and applies to real gases at not high pressures. (ii) At a constant temperature, the solubility of each of the components of a gas mixture in a given liquid is directly proportional to its partial pressure over the liquid and is independent of the total mixture pressure and the content of the other components, that is each component dissolves as if it were present alone. The law applies to near ideal gases having not very high solubilities. The laws were formulated by J. Dalton in 1801 and 1803, respectively.

dealkylation. The abstraction of alkyl groups from molecules of organic substances.

deamination. The abstraction or the replacement of the amino group in organic substances.

decane $\text{CH}_3(\text{CH}_2)_8\text{CH}_3$. A colourless liquid. Found in petroleum products. A constituent of diesel fuel.

decarboxylation. The abstraction of CO_2 from the carboxyl

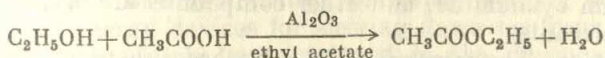
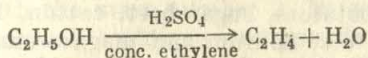


defoliating agents [*L folium*, a leaf]. Substances causing stripping of leaves such as calcium cyanamide or magnesium chlorate. Used to defoliate cotton.

degassing. Decontamination of area, buildings, cloth, etc. affected with a poison gas, removal of noxious gases (from mines).

degree of dissociation. The ratio of the number of dissociated molecules, n , to the sum $n + N$ where N is the number of undissociated molecules, often expressed in per cent. Characterizes equilibria in dissociation reactions in homogeneous (gaseous or liquid) systems, denoted α . For example, acetic acid dissolved in water (0.01M) has α of 4% which means that of each 100 molecules, only 4 ones are dissociated (exist as the ions CH_3COO^- and H^+). The degree of dissociation can be determined by various methods (by measuring the electric conductivity of a solution, the decrease of solution's freezing point from the pure solvent, etc.); it depends on both the nature of the electrolyte and the solution's concentration.

dehydration. The elimination of water from organic substances



Applied to synthesize ethers and esters, resins, plastics, pharmaceuticals, explosives, etc.

dehydrogenation. The abstraction of hydrogen from substances in the presence of catalysts. Many dehydrogenation reactions are of industrial importance, e.g. the dehydrogenation of saturated hydrocarbons, $\text{C}_4\text{H}_{10} \rightarrow \text{C}_4\text{H}_8 + \text{H}_2$, and olefins, $\text{C}_4\text{H}_8 \rightarrow \text{C}_4\text{H}_6 + \text{H}_2$, is used to obtain monomers for the synthesis of rubber. The most familiar catalysts of dehydrogenation are Cr_2O_3 , Fe_2O_3 , and ZnO .

denaturation of proteins [de + *L. nasci*, to be born]. The loss of natural properties such as solubility, hydrophilic properties because of distortions in the molecular structure of proteins. Can be caused by temperature rise, by the action of strong acids and alkalis, heavier metal salts, etc.

de(s)oxyribonucleic acid (DNA). A nucleic acid, a polymer of nucleotides. Incorporates phosphoric acid, deoxyribose, and nitrogenous bases such as adenine, guanine, cytosine, and thymine. Found in the cell nucleus. Plays an important part in the heredity mechanism.

de(s)oxyribose $C_5H_{10}O_4$. A monosaccharide of the pentose series, formed in the reduction of ribose. A constituent of deoxyribonucleic acid.

depolarization. The prevention or decrease of polarization in electrolytic cells and ion current sources with the help of depolarizers added to electrolyte or electrodes. Oxidizers are used to depolarize cathodes, and reducing agents with anodes. Depolarizers either participate in the electrode process or accelerate it thus decreasing electrode polarization.

desalting of water. The removal of salts dissolved in water to make it suitable for drinking or for certain technical uses. Drinking water should contain not more than 1000 mg/litre salts. Desalting can be accomplished by distillation, freezing, ion exchange, or electrodialysis. Desalting of sea water is one of the most important tasks of modern chemical engineering.

desiccants. Substances for drying plants before mechanically harvesting potatoes, sugar beet, cotton, lucerne, buttercup, clover, etc. Sodium and magnesium chlorates, calcium cyanamide, and other compounds are employed as desiccants.

desorption. The removal of an adsorbed substance from the surface of an adsorbent; the process reverse to *adsorption*. Employed in industry and laboratory work to isolate gases, vapours, or dissolved substances from adsorbents.

destruction. The dissociation of substance molecules to fragments, usually free radicals or ions, whose high activity causes many chemical transformations. Chain processes play the most important part in the destruction. The destruction is of importance with polymers, plastics, rubber, fibres, etc. The destruction of polymer materials changes their molecular masses.

destructive distillation. A heating of solid fuels (bituminous coal, lignite, or wood) in the absence of air to 500-600 (semi-coking) or 900-1050 °C (coking) to produce fuel gases, resins, and residues rich in carbon (semicoke, coke, charcoal), and also various chemical substances. See *destructive distillation of wood, coking, cracking, pyrolysis*.

destructive distillation of wood. Thermal decomposition of wood in the absence of air at 450 to 500 °C; gives more than 100 various chemical substances including charcoal,

methanol, acetic acid, acetone, resin, etc. From resin, phenol and other compounds are extracted.

detergent. A substance that has a cleansing action employed for washing clothes, dishes, containers, etc. Soaps, calcined soda and caustic soda, various synthetic surfactants are the best known examples. Some detergents exhibit a bactericide action, for example calcined soda not only washes but also disinfects milk bottles.

detonating gas. A mixture of hydrogen and oxygen in a volume ratio of 2 : 1; the gases combine almost instantaneously to produce a strong explosion when ignited.

detonation [L *detonare*, to thunder, make a loud noise]. The process of a chemical transformation of an explosive accompanied by energy release and propagating from one substance layer to another in the form of waves having a supersonic velocity.

deuterium D (^3H) [Gk *deuteros*, second]. A stable isotope of hydrogen with the mass number 2. Discovered in 1932. Found in natural hydrogen compounds. Obtained by electrolysis and rectification of water. Widely used in nuclear energy devices for slowing down neutrons. Mixtures with tritium are employed in the thermonuclear reaction in the hydrogen bomb.

Devarda's metal (Devarda's alloy). An alloy of copper, aluminium, and zinc in the proportion 50:45:5. Easy to crumble into powder. Used in the analytical chemistry to reduce nitrates and nitrites to ammonia, etc.

Dewar vessel. A vessel for storing and transportation of liquefied gases. Made as glass or metallic vessels with double walls. The space between the walls is exhausted, and the surfaces of the walls are silvered.

dextrin (British gum, starch gum) $(\text{C}_6\text{H}_{10}\text{O}_5)_x$. An intermediate product of the hydrolysis of starch. Dextrins rotate the polarization plane to the right whence their name (from L *dexter*, right). Used in the textile industry, polygraphy, and the manufacture of shoes.

dialysis. The separation of colloidal solutions and solutions of high-molecular-weight substances from low-molecular-weight compounds with the help of a semipermeable membrane, used to remove electrolytes from colloidal solutions. Based on different diffusivities of small and large particles. Applied in industry to purify various

products, for example in the manufacture of synthetic fiber and pharmaceuticals.

diammophos. A concentrated soluble fertilizer containing phosphorus and nitrogen. Made by the neutralization of phosphoric acid with ammonia. Used as a fertilizer, in the impregnation of wood to render it non-flammable. The chemical composition is $(\text{NH}_4)_2\text{HPO}_4$.

diamond (Gk *adamas*, *adamant*, diamond]. An allotropic form of carbon, occurs as single crystals, colourless or coloured by impurities. It is the hardest substance known (hardness 10). Widely applied as an abrasive. From 1955, made synthetically from carbon compounds at high temperatures (1200 to 2000 °C) and pressures (10^{10} Pa). Transparent diamonds cut in a certain way are used as gem stones. Cut diamonds are valued according to their weight (measured in carats), shape, transparency, and sparkle.

diatomite. A rock mainly composed of the skeletons of aquatic plants called diatoms. Used as thermal insulating material and as ballast in building; also applied in the food industry, in the manufacture of sugar from sugar beet, in the production of soap, for the purification of organic substances, the separation of water from petroleum, etc.

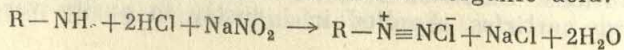
diazo compound. An aromatic compound of the formula $\text{R}-\overset{+}{\text{N}}\equiv\text{N}\bar{\text{X}}$, where R is an aryl radical and X an acid residue or the hydroxyl group, e.g. Cl^- , NO_3^- , OH^- , etc. Contains a group of two nitrogen atoms linked with one aryl radical only. Diazobenzene chloride, $\text{C}_6\text{H}_5\text{N}\equiv\text{NCl}$, is an example. Obtained by diazotizing amines. Widely used in the organic synthesis, in the manufacture of dyes and pharmaceuticals.

diazomethane CH_2N_2 ($\text{H}_2\text{C}=\text{N}=\text{N}$). The simplest aliphatic diazo compound.

Properties: a yellow gas with disagreeable odour, m.p. -145°C , b.p. -23°C ; a strong poison and explosive.

Uses: highly reactive, used in the organic synthesis.

diazotizing. The interaction of aromatic amines with HNO_2 with the formation of an aromatic diazo compound. Usually, diazotizing is carried out by the action of NaNO_2 in the presence of excess inorganic acid:



where R is an organic radical. The process is employed in the production of numerous aromatic compounds, especially azo dyes. The reaction was discovered by Griss in 1858.

dichloroethane $\text{ClCH}_2\text{—CH}_2\text{Cl}$.

Properties: a colourless liquid with strong odour, practically insoluble in water, inflammable, volatile. Toxic. Uses: an effective solvent; used in the organic synthesis for extracting fats and alkaloids. Also employed as insecticide for disinfecting corn, granaries, and vineyard soil.

dichromate. A metal salt of dichromic acid containing the dichromate anion, $\text{Cr}_2\text{O}_7^{2-}$. For example, potassium dichromate, $\text{K}_2\text{Cr}_2\text{O}_7$ (bright red colour, used as strong oxidizer, tanning agent, in the analytical chemistry), sodium dichromate, $\text{Na}_2\text{Cr}_2\text{O}_7$ (chrome tanning).

diene hydrocarbons $\text{C}_n\text{H}_{2n-2}$. Unsaturated open-chain hydrocarbons containing two double bonds between carbon atoms in their molecules. The most important diene hydrocarbons are those with one single bond in between two double bonds such as divinyl, $\text{CH}_2=\text{CH—CH=CH}_2$, isoprene, $\text{CH}_2=\text{C}(\text{CH}_3)\text{—CH=CH}_2$, etc. Diene hydrocarbons are easy to polymerize: their polymerization is used in the production of synthetic rubber.

diesel fuel (diesel oil). Intermediate and heavy fractions obtained in the distillation of petroleum and used as fuel in engines where ignition occurs as a result of compression (diesel engines).

diethyl ether (ether, ethyl ether, sulphuric ether) $\text{H}_5\text{C}_2\text{—O—C}_2\text{H}_5$. The most important ether. Extremely flammable, explosive, toxic.

Properties: a colourless mobile liquid with a characteristic odour; very soluble in organic solvents and itself dissolves many organic substances; rubber swells in ether.

Derivation: by the action of sulphuric acid on ethyl alcohol.

Uses: a solvent, an anaesthetic.

diethylene glycol $\text{HOCH}_2\text{CH}_2\text{—O—CH}_2\text{CH}_2\text{OH}$.

Properties: a colourless syrupy liquid, miscible with water, ethanol, and acetone.

Uses: a solvent for oils, nitrocellulose, polyphenol resins, employed as a plasticizer, an anti-freeze, and as a hygroscopic agent to remove moisture from natural gas.

diffusion [L *diffundere*, to pour in different directions].
Spontaneous interpenetration of gases, liquids, and solids brought in contact with each other.

dimethyl ether $\text{H}_3\text{C}-\text{O}-\text{CH}_3$.

Properties: a colourless gas, chemically inactive, a weak narcotic.

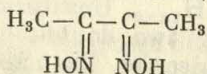
Uses: methylation of aromatic amines, the preparation of dimethyl sulphate, as a solvent.

dimethyl formamide $(\text{CH}_3)_2\text{NCOH}$.

Properties: a colourless mobile liquid with a peculiar odour.

Uses: as a solvent in the production of polyacrylonitrile fiber (Nitron), in dyeing leather, paper, wood, viscose, etc.; also employed for absorbing HCl , SO_2 , and other acidic gases.

dimethylglyoxime (Chugaev's reagent)



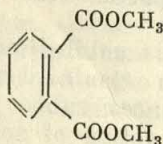
Properties: colourless crystals very soluble in ethanol, ether, and solutions of alkalis.

Uses: in the analytical chemistry for the determination of Ni^{2+} , Pd^{2+} , Fe^{2+} , and Co^{2+} . First described as a reagent for nickel by Chugaev in 1905.

dimethylhydrazine. A colourless liquid, exists as two isomers, a symmetric, $\text{CH}_3\text{NH}-\text{NHCH}_3$, and an asymmetric one, $(\text{CH}_3)_2\text{N}-\text{NH}_2$.

Uses: a combustible component of liquid rocket fuels.

dimethyl phthalate. Methyl ester of phthalic acid



Properties: a colourless liquid with weak odour; soluble in water only slightly, soluble in many organic solvents.

Uses: insect repellent; nontoxic and does not irritate skin.

dimethyl sulphate $(\text{CH}_3)_2\text{SO}_4$.

Properties: a colourless liquid, slightly soluble in water; in aqueous solutions undergoes saponification accelerated in the presence of acids. Odourless, very toxic.

Uses: a methylating agent.

dinitrophenol. Any of the compounds of the formula $C_6H_3(NO_2)_2OH$.

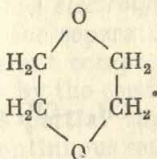
Properties: colourless or yellowish crystals, explosive, poisonous, strongly irritate skin. Highly acidic.

Derivation: by nitrating phenol.

Uses: the manufacture of synthetic dyes, as herbicides and insecticides; also employed as indicators in pH determinations.

diol. Dihydric alcohol. See *glycol*.

dioxane



Properties: a colourless flammable liquid with a weak odour. A good solvent for cellulose acetate, resins, rubber, mineral and vegetable oils.

Uses: a solvent for dyes; used in the purification of petroleum oils.

dipole. A polar molecule or any electroneutral system of positive and negative charges whose electrical centres do not coincide. The distance between dipole poles is called the dipole length. The dipole length characterizes molecule's polarity: the larger this length the more polar the molecule.

diphenyl (biphenyl, phenylbenzene) $C_6H_5-C_6H_5$.

Properties: colourless crystals, very soluble in organic solvents.

Occurrence: contained in anthracene oil which is isolated from coal-tar.

Uses: a mixture of diphenyl and diphenyl ether is employed as a high-temperature heat transfer agent.

diphenylamine $C_6H_5-NH-C_6H_5$.

Properties: white crystals with a weak characteristic odour, turn dark when exposed to air.

Uses: the determination of oxidants, as a redox indicator.

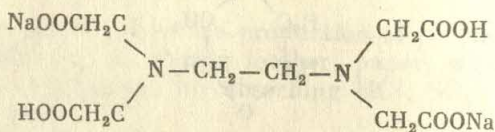
disaccharide. Any of a group of crystalline carbohydrates whose molecules are composed of two monosaccharide residues. Disaccharides occur in plant and animal tissue (e.g. saccharose, maltose, etc.). When hydrolyzed disaccharide molecules dissociate to give two monosaccharides.

Many disaccharides are valuable components of food, they are also used in microbiology and medicine.

disinfection. A destroying of harmful bacteria with the help of chemicals (formaldehyde, sulphur(IV) oxide, lime-white, chloropicrin, etc.).

disinsectization. A destroying of insect pests with the help of chemicals (dichloroethane, chloropicrin, etc.) in warehouses etc.

disodium edetate (disodium salt of ethylenediaminetetraacetic acid)



A white powder soluble in water and alkalis, aqueous solution has pH of about 6. Forms very stable complexes with most cations. Used in the analytical chemistry to determine many cations and anions, e.g. Ca, Mg, Cu, Co, Ni, Zn, Fe, Mo, Al, rare earth elements, Th, U, SO_4^{2-} , PO_4^{3-} , CN^- (see *chelatometry*). Also used in potentiometric, polarographic, ammetric procedures, for masking, in medicine to treat poisonings, as a preservative, etc.

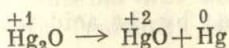
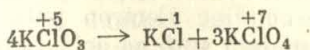
disperse phase. A system of minute particles (solid, liquid, or gaseous) suspended in a liquid, gaseous, or solid medium (dispersion medium). Examples are milk where particles of fat are suspended in water, various emulsions, suspensions, fogs, foams, and smokes. Disperse systems are studied by the chemistry of colloids.

dispersion. A reducing of solids or liquids to minute particles in some medium to prepare powders, suspensions, emulsions. Used to obtain colloidal systems and disperse systems in general. The dispersion of liquids is usually called spraying if it is carried out in a gas phase and emulsification if in another liquid. The dispersion of solids involves their crushing.

dispersity. A quantity characterizing particle dimensions in disperse phases.

disproportionation. The autoreduction-autooxidation process resulting in simultaneous formation of compounds where the element occurs in the higher and lower oxidation

states as compared to the initial substance, e.g.:



dissimilation. The dissociation of organic substances in vivo with release of energy needed for living activity. The most important dissimilation processes are respiration and fermentation.

dissociation electrolytic. See *electrolytic dissociation*.

distillation. The process for separating mixtures of liquids into fractions of different compositions by their partial vaporization followed by the condensation of the vapour. Simple distillation is partial vaporization of a boiling liquid mixture with continuous removal and condensation of the vapour. The liquid obtained by the condensation is called distillate. Distillation is employed in chemistry, in the chemical and petroleum industries.

distilled water. Water purified from other substances by distillation.

dithizone (diphenylthiocarbazone) $\text{C}_6\text{H}_5\text{—N=N—CS—NH—NH—C}_6\text{H}_5$.

Properties: black-blue crystals insoluble in water, soluble in chloroform and carbon tetrachloride. Forms coloured chelate compounds soluble in CHCl_3 , CCl_4 , and CS_2 with many cations.

Uses: separation and high-sensitivity determination of Bi, Cd, Hg, Zn, Cu, Pb, Co, etc.

divinyl. See *1,3-butadiene*.

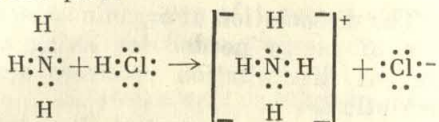
dolomite $\text{CaCO}_3 \cdot \text{MgCO}_3$. A rock forming mineral, usually contains clays and limestone.

Uses: a refractory, a flux in metallurgy, a fertilizer. Also used in the manufacture of lime, magnesium salts, and magnesium metal.

donor. In chemistry an atom or a group of atoms that form chemical bonds using their lone electron pairs for filling free orbitals (energy levels) of acceptors. See *donor-acceptor bond*.

donor-acceptor bond (coordination bond). A chemical bond between an atom and another atom or group of atoms which involves a lone electron pair of one of the participants (a donor) and a free orbital of another one (an acceptor). Such bonds often occur in complex compounds.

They only differ from the usual covalent bond in the origin of the bonding electron pair. For example the reaction of ammonia with an acid occurs with the addition of a proton lost by the acid to the donor (nitrogen) lone electron pair:



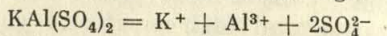
All the four nitrogen-hydrogen bonds are equivalent in the NH_4^+ ion though they differ in their origin. Nitrogen, oxygen, phosphorus, sulphur, etc. atoms may act as donors; proton and atoms with in complete octets such as atoms of Group III elements and also atoms containing unfilled energy levels in their valence shells may be acceptors. See also *covalent bond*.

double chemical bond. A bond between two carbon atoms or atoms of other elements involving four electrons as in ethylene, $\text{CH}_2=\text{CH}_2$, acetone, $\text{CH}_3-\text{C}-\text{CH}_3$, and



many other compounds.

double salts. Compounds of the type $\text{KAl}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ (potassium alum). Exist only in the solid state; dissociate to ions upon dissolution in water, e.g.:



drying oil. A liquid made from vegetable oils or fats, used in the manufacture of oil paints and lacquers.

duralumin (durable + aluminium). A strong lightweight alloy of aluminium with copper, magnesium, manganese, silicon, and iron. The total content of elements other than aluminium is 6 to 8 per cent.

Uses: aircraft, buses, etc.

dusting clays. Finely divided pulverized clays that can serve as diluents and carriers in the preparation of insecticide dusts and aid in adhesion of the insecticide to foliage.

dynamite. A mixture containing glyceryl trinitrate as its principal explosive component; usually also contains inert (talc, tripolite) and active (charcoal, a mixture of wood powder and saltpetre) fillers. Very dangerous.

dysprosium [Gk *dysprositos*, difficult of access] Dy. A Group III element of the 6th period of the Mendeleev Periodic

Table of Elements, atomic number 66, atomic mass 162.50. Belongs to lanthanides. Discovered in 1886 by Lecoq de Boisbaudran. The most paramagnetic substance of all known. Valence +3.

E

earth's crust (lithosphere). A solid outer layer of the earth about 16 km thick; the most abundant elements in earth's crust are O, Na, Si, Al, Fe, Ca, K, and Mg. They form oxides, silicates, aluminium silicates, carbonates, sulphates which occur in various rocks.

ebonite [Gk *ebenos*, ebony]. Vulcanized rubber containing a large percentage of sulphur (30%), usually black or darkbrown. Resistant to the action of acids. Used as material for electrical insulators.

ebullioscopy [L *ebullire*, to boil up]. A procedure for the determination of the molecular weight of a dissolved substance by measuring an increase in solution's b.p. from that of the pure solvent. Based on Raoult's law.

einsteinium [after Albert Einstein] Es. A radioactive element of the actinide family, atomic number 99. The longest lived isotope is ^{259}Es ($T_{1/2}$ of about 320 days). First detected in 1958 in the debris from the hydrogen bomb explosion. Resembles holmium in its chemical properties.

electrical conductivity. The ability of substances to transmit electricity under the action of an external electrical field. If electrons are charge carriers as, e.g. in metals and most semiconductors, the phenomenon is called electronic conductivity. Ionic conductivity is characteristic of solutions of electrolytes and ionic crystals where ions act as charge carriers. Unlike electronic conductivity ionic conductivity is accompanied by transport of substance (ions), which is essential to electrolysis.

electrochemical equivalent. The mass of a substance that must be deposited, according to Faraday's law, upon passage of one unit of electricity through an electrolyte, $a = w/F$, where w is the chemical equivalent, F the Faraday constant.

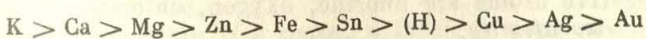
electrochemical methods of analysis. Most of these are based on electrolysis. Here belong electrogravimetric analysis,

- internal electrolysis, contact exchange of metals (cementation), polarographic analysis, coulometry, etc. Electrochemical methods also include techniques based on measurements of electrical conductivity (conductometry) and electrode potentials (potentiometry). Some electrochemical methods are employed to detect the end point of titration (ammetric titration, conductometric titration, potentiometric titration, and coulometric titration).
- electrochemistry.** A branch of physical chemistry dealing with chemical transformations involved in electrical processes. Modern electrochemistry studies the properties of systems containing ions and the processes that occur at interfaces separating such systems from metals.
- electrogravimetric analysis.** A method of quantitative analysis based on the use of electrolysis for the determination of substances. The method consists in weighing deposits formed on one of the electrodes during electrolysis; it can be applied not only for quantitative determination of copper, nickel, lead, etc. but also for the separation of mixtures of substances.
- electrolysis.** The decomposition of electrolytes, in solutions or melts, caused by electrical current and involving the loss or the addition of electrons by ions or molecules of dissolved substances. The addition of electrons occurs at the cathode and results in the formation of the reduction products there. The loss of electrons at the anode is accompanied by the formation of the oxidation products. In the chemical industry, electrolysis is employed for the isolation of many metals and various substances (alkalis, chlorine, hydrogen, oxygen, some organic compounds). Electrolysis is applied in the analytical chemistry (electrogravimetric analysis), in electroplating for producing various metal coatings; it is used for charging storage batteries, etc.
- electrolyte.** A solution of an acid, an alkali, or a salt where the decomposition of molecules into ions occurs; a substance that shows electrical conductivity in the molten or dissolved state. An aqueous solution of NaCl is a typical electrolyte. Electrolytes may be strong (the degree of dissociation about unity) and weak (the degree of dissociation is near zero).
- electrolytic dissociation.** The decomposition of molecules of electrolytes (acids, bases, and salts) into ions as a result

of dissolution. The dissociation occurs because of interactions between electrolyte molecules and polar solvent molecules, e.g. water molecules, which generate an electric field. The process is reversible, e.g. $\text{HCl} \rightleftharpoons \text{H}^+ + \text{Cl}^-$. The ions formed interact with solvent molecules; with water, they give aqua complexes of a constant or variable composition, e.g. H_3O^+ , the hydrated proton or hydroxonium ion. The degree of the dissociation of the dissolved substance, α , is used as a quantitative measure of the dissociation process. The classical theory of the electrolytic dissociation was developed by Arrhenius in 1887.

electrometallurgy. A group of methods employed for the isolation and purification of metals by electrolysis at usual temperatures and electrolysis of melts or for melting metals by electrical means.

electromotive series (displacement series, activity series). An arrangement of the metals in the order of their activity in redox reactions (the reducing action decreases from left to right):



Any metal standing before hydrogen can displace hydrogen from acids.

electron (e^-). A stable negatively charged elementary particle with a mass of 9.11×10^{-31} kg. Electron's charge is used as the negative charge unit. Discovered by Sir J. Thomson in 1897. Electrons are one of the constituents of the atom. Electrons moving about a nucleus form electron shells which determine the electrical, optical, and chemical properties of atoms and molecules. Electrons participating in the formation of chemical bonds are of crucial importance; these are mostly outer shell electrons (in the atoms of subgroup A elements). In the subgroups B except for IIB, atoms can also participate in bonding with their outermost but one shells.

Electron. An alloy with magnesium as the major component (about 90 per cent). Used in aircraft.

electron affinity. An energy liberated when an atom, molecule, or radical accept an electron; usually expressed in eV per atom or kJ per mole. This quantity is of importance for the understanding of the nature of chemical bonding and processes of the formation of negative ions.

The larger the electron affinity the easier the addition of electrons to the atom. Metals have zero or near zero electron affinities; electron affinities of non-metals are the larger the nearer non-metals stand to a noble gas in the periodic system; therefore within a row, non-metallic properties increase in passing from the first to the last member.

electron diffraction. The phenomenon used in the study of the structure of crystals, surfaces, molecules, etc.

electron microscopy. The method for studying minute details of substance structures with the help of an electron microscope which allows observing details of about 10^{-4} to 10^{-8} cm dimensions.

electronegativity. A quantitative measure of the ability of an atom to attract electrons in the formation of covalent bonds which allows obtaining a quantitative estimate of the degree of bond ionicity. The attraction of electrons by an atom depends on many factors such as its ionization energy, electron affinity, etc. Thus chlorine in HCl is more electronegative than hydrogen. The most electronegative atoms are fluorine, oxygen, chlorine. See also *electron affinity*.

electrophoresis [electro + Gk *phoresis*, a bearing]. Cataphoresis. The migration of electrically charged colloidal particles in a liquid or gaseous medium under the action of an external electric field. Used to remove water from peat, dyes, in the purification of clays and kaolin, for coagulating latex, smokes, and mists, in the study of solution compositions, etc.

electroplating. The technique for depositing a coating of metal by electrolysis for preventing corrosion, for decorative or some special purposes.

electrovalent bond. See *ionic bond*.

elemental analysis. A combination of procedures for the quantitative determination of the percentages of elements in organic substances. Elemental analysis involves two steps: (i) the decomposition of the substance with the formation of inorganic compounds containing the element to be determined, e.g. CO_2 , H_2O , etc.; (ii) the determination of the amount of the inorganic products formed.

elements, chemical. A chemical element that includes atoms with the same nuclear charge. All the elements have

isotopes. Up to 1975, 106 chemical elements, natural and synthetic, were known. Patterns of the properties of chemical elements are reflected in the periodic system of elements.

emery. A finely granular rock, colour black or black-green, contains much corundum. Used as an abrasive.

emanation. See *radon*.

emulsion. A liquid with microscopic particles of another liquid suspended in it; for example, milk is a suspension of fat particles in water. Emulsions play an important role in the manufacture of soap, in the food industry (butter, margarine), in processing natural rubber, in the manufacture of various lubricants, in medicine, painting, etc.

enamel. (i) A mixture containing a varnish base needed to produce a film coating and finely ground pigment; (ii) a glassy substance fused to surfaces of metals to prevent corrosion or for decorative purposes. The principal components of almost all enamels are SiO_2 , B_2O_3 , alkali and alkaline earth metal oxides, Al_2O_3 , TiO_2 , lead and zinc oxides, etc.

endothermic reaction [Gk *endon*, within]. A reaction accompanied by absorption of heat, e.g. the decomposition of CaCO_3 into CaO and CO_2 . Other examples are the reduction of metals from their ores, photosynthesis in plants, etc.

enzyme [Gk *en*, in + *zyme*, leaven]. An organic catalyst of the protein nature produced by living cell protoplasm. Enzymes are necessary participants of all biochemical processes, they are characterized by high activity and selectivity. More than 800 enzymes are known at present. The knowledge of the properties of enzymes is very important for practical purposes.

eosin. An insoluble dye obtained by the bromination of fluorescein.

Uses: colouring of cosmetics, the manufacture of copying pencils, the sensibilization of photographic emulsions. Also used as indicator in the analytical chemistry.

ephedrine. An alkaloid of ephedra, also obtained synthetically. Has a stimulating action on the central nervous system, causes constriction of blood vessels. Used in the form of ephedrine hydrochloride to treat asthma, colds, narcotic intoxications.

epinephrine. See *adrenaline*.

epoxy (epoxide) resins. Synthetic resins derived from 1-chloro-2,3-epoxypropane, $\text{H}_2\text{C}-\text{CH}-\text{CH}_2\text{Cl}$, and phenols,



stable to the action of chlorine, acids, firmly stick to metal surfaces. Used in the manufacture of adhesives, plastics, electrical insulators.

Epsom salts $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$. Magnesium sulphate.

equilibrium chemical. A dynamic equilibrium in a reversible reaction when the rate of the forward reaction is equal to that of the reverse reaction, $\text{A} + \text{B} \rightleftharpoons \text{C} + \text{D}$. Chemical equilibria are characterized by ratios of the concentrations of the reagents constant at a given temperature. See *mass action law*.

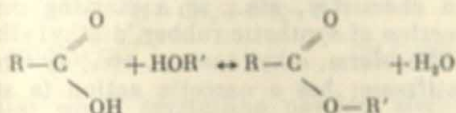
equivalence point in titration. The point at which the numbers of equivalents of reactants are equal to each other.

equivalent, chemical, the combining weight. The mass of a substance which adds or replaces 1.008 mass units of hydrogen or 15.9994/2 mass units of oxygen. The equivalent of an acid is equal to its molecular weight divided by the acid's basicity (by the number of hydrogen atoms it contains). For instance, the equivalent of H_2SO_4 is equal to the molecular weight of sulphuric acid divided by 2. The equivalent of a salt is equal to its molecular weight divided by the sum of charges of the cations or anions it contains (e.g. divided by 3 for Na_3PO_4). In redox reactions, the equivalent of the oxidizing agent is equal to its molecular weight divided by the number of electrons accepted by a reduced element atom. For example, KMnO_4 undergoes reduction to Mn(II) in acidic media, each manganese atom accepting 5 electrons; the equivalent of KMnO_4 in these reactions is therefore equal to its molecular weight divided by 5. Equivalent values may vary depending on the number of electrons accepted by an oxidizing agent. For instance, in near neutral media, the manganese atom of KMnO_4 accepts 3 electrons to form MnO_2 ; the equivalent of KMnO_4 will then be equal to the molecular weight divided by 3. See *equivalent electrochemical*.

erbium (from Ytterby, a town in Sweden) Er. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 68, atomic mass

167.26, of the lanthanide series. Discovered by Mosander in 1843. The oxidation state +3. Used in the manufacture of certain alloys, glass that effectively absorbs infrared radiation.

ester. An organic substance derived by replacing hydrogen of an acid by an organic radical or group. Esters are contained in essential oils, are the major constituents of plant and animal fats and oils. Many esters can be obtained synthetically by the esterification process:



esterification. The preparation of esters from acids and alcohols:



The reaction is reversible; the hydrolysis of esters is called saponification. Esterification is usually carried out in the presence of catalysts (strong inorganic acids).

ethanol. See *ethyl alcohol*.

ether. An organic compound of the type $\text{R}-\text{O}-\text{R}$ where R are identical or different radicals such as CH_3- , C_2H_5- , C_6H_5- , for example diethyl ether, $\text{C}_2\text{H}_5-\text{O}-\text{C}_2\text{H}_5$. Ethers are prepared by heating alcohols in the presence of H_2SO_4 , and using other procedures.

ethyl acetate. Ethyl ester of acetic acid, $\text{CH}_3\text{COOC}_2\text{H}_5$, a colourless volatile liquid used as solvent, a component of fruit essences.

ethyl acetoacetate (acetoacetic ester, ethyl-3-oxobutanoate*) $\text{CH}_3\text{COCH}_2\text{COOC}_2\text{H}_5$.

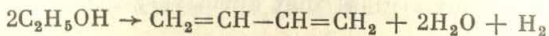
Properties: a colourless mobile liquid of fruity odour.

Uses: the manufacture of pharmaceuticals (aminopyrine, mepacrine, vitamin B_1), dyes for colour photography; the organic synthesis.

ethyl alcohol (ethanol*, grain alcohol, spirits of wine) $\text{C}_2\text{H}_5\text{OH}$.

Properties: a colourless mobile liquid with a pungent taste, b.p. 78°C , miscible with water, alcohols, ether, glycerol, and other solvents, gives colourless flame when ignited, forms azeotropic mixtures with many substances. A typical alcohol; ethanol vapour is converted to 1,3-

butadiene (divinyl) upon passage over catalysts at 400 °C (Lebedev's reaction):



Derivation: by fermentation of molasses, grain, etc.; by the hydrolysis of wood and other plant materials; from sulphite pulp; by the hydration of ethylene.

Uses: as a solvent in the manufacture of lacquers and dyes, pharmaceuticals, explosives, in photography and in household chemistry, etc.; as a starting material for the production of synthetic rubber, diethyl ether, acetaldehyde, chloroform, ethyl acetate, etc.; as a rocket fuel; as an antifreeze; has a narcotic action (a stimulating action).

ethyl cellulose. An ethyl ether of cellulose, used in the manufacture of plastics, lacquers, electrical insulators, etc.

ethyl chloride (chloroethane*) $\text{C}_2\text{H}_5\text{Cl}$.

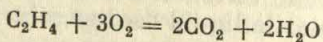
Properties: a colourless volatile liquid (b.p. 12.5 °C) with a characteristic odour, flammable. When comes in contact with living tissue quickly vaporizes and cools it.

Uses: for refrigeration, in medicine (to induce narcosis).

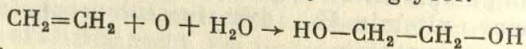
ethylation. The replacement of hydrogen by the ethyl group, $-\text{C}_2\text{H}_5$, in organic compounds.

ethylene $\text{CH}_2=\text{CH}_2$. The simplest olefin, ethylene and its homologues occur in natural and petroleum gases.

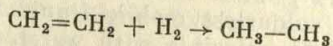
Properties: a colourless gas with a pleasant odour, lighter than air, slightly soluble in water, gives a luminous flame:



Typical reactions are addition reactions, e.g. ethylene turns solutions of KMnO_4 colourless because KMnO_4 is reduced by it while ethylene adds oxygen and water to give a dihydric alcohol, ethylene glycol:



Ethylene adds hydrogen in the presence of catalysts (Pt, Pd, or Ni):



Derivation: cracking of petroleum and natural gas.

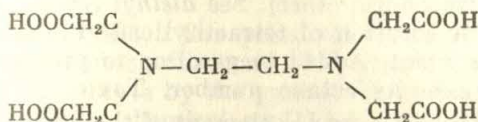
Uses: the manufacture of polyethylene, ethylene oxide, ethyl-benzene, and ethyl alcohol; mixtures of ethylene

with oxygen are used in medicine (narcosis); admixtures of ethylene in the air increase growth rate of certain plants, in particular the rate of fruit ripening.

ethylene chlorohydrin (2-chloroethanol*) $\text{CH}_2\text{OH}-\text{CH}_2\text{Cl}$.

Used as a solvent in the organic synthesis; poisonous.

ethylenediaminetetraacetic acid (EDTA, ethylenedinitrilo-tetraacetic acid)



Properties: white crystalline powder, slightly soluble in water, insoluble in most organic solvents, soluble in alkalis. A tetrabasic acid, one of the most important organic chelating agents forming stable chelate compounds with metal ions.

Derivation: by the condensation of ethylenediamine with monochloroacetic acid.

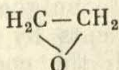
Uses: in the form of a disodium salt is used in the textile, leather, paper industries, in the manufacture of lacquers and dyes, rubber, in the production of metals, in colour photography, for softening water. In the analytical chemistry, EDTA is used to determine more than 60 elements. In medicine, it is employed to remove radioactive and toxic metals from organisms, as an anticoagulant of blood, etc.

ethylene glycol (1,2-ethanediol*, glycol) $\text{CH}_2\text{OH}-\text{CH}_2\text{OH}$.

The simplest dihydric alcohol, liquid. Made from ethylene. Mixtures with water are used as antifreeze in automobile radiators. Also used in the manufacture of plastics, synthetic fibre, solvents, explosives, etc.; in the tobacco and textile industries, in perfumery, etc. Poisonous.

ethylene hydrocarbons (alkenes, olefins). Unsaturated hydrocarbons of the general formula C_nH_{2n} . An olefin contains one double bond. All olefins are reactive substances used in various organic syntheses.

ethylene oxide (1,2-epoxyethane*)



Properties: a colourless gas at ordinary temperatures, liquefies at 11 °C, flammable. Typical reactions are additions with ring opening.

Uses: the manufacture of ethylene glycol and its ethers, ethanolamines, azo dyes, dioxane, acetaldehyde, etc. Also used as insecticide and disinfectant. Has a narcotic action.

ethyl ether (sulphuric ether). See *diethyl ether*.

ethyl fluid. A solution of tetraethyllead, $\text{Pb}(\text{C}_2\text{H}_5)_4$, in an organic solvent. Added to gasoline to prevent knocking and increase its octane number. Toxic.

europium Eu. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, belongs to the lanthanide family, atomic number 63, atomic mass 151.96, a metal, has two stable isotopes, ^{151}Eu (47.77%) and ^{153}Eu (52.23%). The oxidation states in compounds +2, +3. Forms pink or pale-yellow salts.

eutectic [Gk *eutektos*, easily fused]. A close mixture of solids (alloy) with a melting point lower than that of any other combination of the same components. Many technological alloys have eutectic compositions, e.g. Wood's metal, various solders, eutectic pig iron, alloys for casting, etc. Many minerals are also eutectic mixtures.

exothermic reaction. A reaction accompanied by release of heat, as burning of coal.

experiment. A test or trial of something under strictly controlled conditions.

explosive. A substance or a mixture of substances which undergoes a rapid self-developing chemical change accompanied by release of much heat and evolution of gas. The most important chemical compounds that can be used as explosives are polynitro derivatives of aromatic and other hydrocarbons such as trinitrotoluene (TNT), trinitrophenol (picric acid), nitroamines, e.g. cyclonite, esters of nitric acid and polyhydric alcohols such as nitroglycerol, nitrocellulose, salts of nitric acid, e.g. ammonium nitrate. The most important mixtures are gunpowders, mixtures of nitroglycerol and nitrates, ammonites, dynamites, oxyliquits.

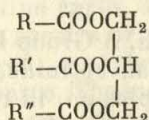
extraction. A separation technique of a mixture of liquids or solids into components by using selective solvents (extractants) in which the components have different

solubilities. Employed in the chemical, petroleum, food industries, in metallurgy, in the manufacture of pharmaceuticals, in the analytical chemistry, etc.

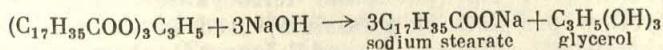
F

Faraday's laws (1833). The principal laws of electrolysis according to which the mass of any substance liberated from an electrolyte by the passage of current, m , is proportional to its chemical equivalent, w , to the current, i , and to the time for which it flows, t : $m = \frac{w}{F} it$, where F is Faraday's number.

fat. An ester of glycerol and fatty acids of the general formula



where R, R', and R'' are the radicals of acids. Fats are biologically important substances, they occur in protoplasm of cells and serve as storage materials. Fat of animals is usually solid except for fish-oil, vegetable fats are liquids and called oils. Chief constituents of animal fats are glycerides of solid saturated acids such as palmitic and stearic acids. Vegetable oils are mainly composed of glycerides of unsaturated acids, they can be converted to solid fats by hydrogenation. Fats are insoluble in water, their suspensions or emulsions can be prepared by shaking them with water for a long time; milk is a natural emulsion of fat. Fats are soluble in organic solvents. Heating them with alkalis results in saponification of fats with the formation of glycerol and soap:



fatty acid. Any of numerous carboxylic acids with open chains such as acetic acid, CH_3COOH , and butyric acid, $\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{COOH}$. In plants and animals, fatty

acids are formed in metabolic processes involving carbohydrates and fats; the prevailing components of fats are esters of the higher fatty acids, viz. palmitic, $\text{CH}_3 - (\text{CH}_2)_{14} - \text{COOH}$, oleic, $\text{CH}_3 - (\text{CH}_2)_7 - \text{CH} = \text{CH} - (\text{CH}_2)_7\text{COOH}$, etc.

feldspar. The general name for a group of sodium, potassium, calcium, and barium aluminosilicates, the most abundant rock forming minerals (about 50% of the mass of Earth's crust). Colour white, pink, or grey. Used in the ceramic, porcelain, glass, cement industries and as ornamental stone.

fermentation. The process of decomposition of organic substances, mostly carbohydrates, under the action of bacteria, yeast, or their enzymes; accompanied by release of energy consumed by the microorganisms. Fermentation with the formation of ethyl alcohol is used in wine and beer manufacture, lactic fermentation in cheese-making, etc.

fermium [after Fermi] Fm. A Group III radioactive element, atomic number 100, an actinide, discovered in 1953 in the thermonuclear explosion, in the same series of experiments as einsteinium. The longest lived isotope ^{257}Fm , $T_{1/2} = 79$ days. A chemical analogue of erbium, a lanthanide.

ferric alum. A double salt of ferric sulphate and an alkali metal or ammonium sulphate. The most familiar example is ammonium ferric alum, $\text{NH}_4\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ used in tanning and dyeing.

ferrite. A compound of ferric oxide with another element oxide having valuable magnetic and semiconductor properties, used in various fields of electronics, e.g. in computers.

ferroalloy. An alloy of iron with Si, Mn, Cr, W, Mo, V, Ti or some other elements, used for deoxidizing and alloying steel. The most common ferroalloys are ferrosilicon, ferromanganese, and ferrochromium.

ferrocyanide. A compound containing the complex ion $[\text{Fe}(\text{CN})_6]^{4-}$, e.g. potassium ferrocyanide, $\text{K}_4[\text{Fe}(\text{CN})_6]$ (yellow prussiate of potassium) used in the analytical chemistry for the detection of Fe^{3+} and for the preparation of Berlin blue.

ferrous metals. Iron and its alloys (steel, pig iron, ferroalloys).

fertilizer. Any material used to improve quality of soil, nutrition of plants, and increase plant growth. Classified as inorganic, organic, mixed, bacterial. See also *composite fertilizers*.

filler. A compound introduced into rubber or latex (e.g. carbon black, chalk, talc, and magnesium oxide) and plastics (sawdust, asbestos, etc.) to improve their characteristics; for example, carbon black increases durability of rubber goods and makes them cheaper. Fillers (talc, chalk, kaolin) are sometimes added to insecticide dusts.

filter, paper. A porous paper used to separate suspended solids from liquids; leaves no ash after it has been burnt. Several kinds of filters differing in pore dimensions are manufactured. Used in the analytical procedures.

fire-damp. An explosive mixture of methane, CH_4 , and air, formed in coal mines.

flame photometry. One of the spectral methods. Used to determine alkali, alkaline earth, and some other elements by measuring atomic spectra or molecular bands. Flames produced by hydrogen, acetylene, or illuminating gas serve as excitation source. The method is highly sensitive, rapid, and accurate, can be applied to determine the elements in salts, mixtures, solutions, minerals, and biological objects.

flotation (earlier floatation). A method for separating minerals from waste rock based on different wetting of mineral and waste rock particles. Widely applied in metallurgy of nonferrous metals, for concentrating coals, in the chemical industry for separating salts, in the food industry, etc.

fluorescence. Short-lived luminescence.

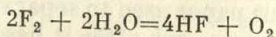
fluorides of metals. Compounds of fluorine with metals, as KF , NaF , CaF_2 , or UF_6 .

fluorinated hydrocarbons. The products of the substitution of fluorine for hydrogen in various organic substances. Fluorinated hydrocarbons are used as constituents of lubricants resistant to heating and oxidation, hydraulic fluids, plastics (Teflon), heat-resistant rubbers, coatings, fire extinguishers, electrotechnical materials, non-toxic refrigerants (Freons), insecticides, and fungicides. Also used in the production of new materials (e.g. artificial vessels and heart valves in medicine). Fluorinated hydrocarbons are interesting models for the study of the nature

of hydrogen bonding, the mechanisms of rearrangements, etc.

fluorine [L *fluere*, to flow] F. A Group VII element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 9, atomic mass 18.9984, one stable isotope, ^{19}F . First isolated by Moissan in 1886.

Properties: a pale yellow gas, the most reactive of all the elements, the oxidation state in compounds -1 ; has the largest electron affinity. Reacts with all elements including some inert gases. Decomposes water:



Destroys many substances, reacts with wool and rubber with ignition, reacts with most metals at room temperature (Fe, Cu, Ni are stable to fluorine because of the formation of metal fluoride protecting films, and the gas is transported in special steel cylinders).

Occurrence: the chief minerals are fluorspar (fluorite), CaF_2 , cryolite, Na_3AlF_6 , and fluorapatite (rockphosphate), $\text{Ca}_5(\text{PO}_4)_3\text{F}$. Fluorite is used as a flux, and hence the name of the mineral and the element.

Derivation: by the electrolysis of molten $\text{KF} \cdot 2\text{HF}$.

Uses: as an oxidizer in liquid rocket fuels, in the manufacture of UF_6 for separating the isotopes of uranium, in the manufacture of other fluorides. More widely applied in the form of its compounds such as hydrogen fluoride, aluminium fluoride, silicon fluorides, and, especially, fluorinated hydrocarbons.

fluorite. See *fluorspar*.

fluorimetry (luminescent analysis). The determination of substances from the intensity of fluorescence arising under UV irradiation.

fluoroplastics. Plastic polymers of trifluorochloroethylene (fluorothene) and tetrafluoroethylene (Teflon).

fluorspar (fluorite) CaF_2 . A mineral.

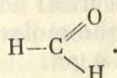
Properties: colour yellow, blue, violet, sometimes violet-black; colourless crystals occur only rarely; brittle. Usually contains impurities (rare earth elements, uranium, etc.). Pure fluorite crystals are highly transparent in the ultraviolet and infrared regions of the spectrum, give bright luminescence under cathode rays and ultraviolet irradiation, fluoresce when heated (show thermoluminescence).

Uses: in metallurgy as a constituent of low-melting slags, in the chemical industry (source of fluorine, the manufacture of artificial cryolite and a number of fluorine compounds), in the manufacture of enamels and glazes. Colourless transparent crystals of fluorite are employed in optics (the manufacture of lenses). Fluorite crystals with admixtures of rare earth elements and iron can be used as laser materials.

flux. In metallurgy inorganic substances added to ores to decrease their melting points and facilitate the separation of metals from waste rock.

forensic chemistry. A science of the chemical study of material evidence; uses fast, accurate, and sensitive analytical methods such as spectral, luminescence, radioactivation methods.

formaldehyde [L *formica*, an ant]



Properties: a colourless gas with a pungent odour, very soluble in water, poisonous (causes coagulation of protein), polymerizes to give paraformaldehyde, $(-\text{CH}_2\text{O}-)_n$, a solid product with n of 8 to 100.

Derivation: by the oxidation of methanol with air oxygen in the presence of a catalyst (Cu, Pt); by the oxidation of methane.

Uses: in the manufacture of dyes, pharmaceuticals (methenamine), as a disinfectant (formalin). Especially large amounts of formaldehyde are used in the manufacture of phenol-formaldehyde resins and plastics. See also *paraformaldehyde*.

formalin. A 40% solution of formaldehyde in water, used as a disinfectant, a preservative for zoological purposes, in tanning leather, for treating seeds, embalmment.

formate. A salt or ester of formic acid, HCOOH .

formic acid HCOOH . The simplest monocarboxylic acid.

Properties: a colourless liquid with a pungent odour, caustic, poisonous. Shows the properties of both acids and aldehydes, for its molecule contains both carboxylic

and aldehyde groupings, $\text{HO}-\text{C} \begin{array}{l} \nearrow \text{O} \\ \searrow \text{H} \end{array}$. Decomposes when

heated with sulphuric acid, $\text{H}_2\text{SO}_4 : \text{HCOOH} = \text{CO} + \text{H}_2\text{O}$ (a procedure for the preparation of carbon monoxide).

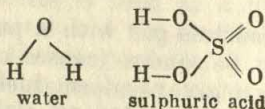
Occurrence: found in ants from which it was first isolated, in nettle, in fir-needles, in bee poison.

Derivation: in industry is made from carbon monoxide and sodium hydroxide: $\text{CO} + \text{NaOH} = \text{HCOONa}$. Pure acid is isolated by the action of H_2SO_4 on HCOONa .

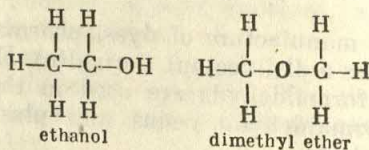
Uses: in the chemical, textile, and food industries, in medicine (a solution in ethanol). Formic acid derivatives such as formamide and dimethylformamide also have practical applications.

formula, chemical. An expression of the elementary composition of a compound by a combination of the symbols of chemical elements and figures. See also *formula, structural*.

formula, structural. A chemical formula showing how the atoms are arranged in the molecule and in what valence states do they occur, e.g.



The chemical formula $\text{C}_2\text{H}_6\text{O}$ may refer to two compounds with different properties:



Structural formulas are refined and made more sophisticated as our knowledge of the structure of substances is improved.

fossil wax. See *ozocerite*.

fractional crystallization. A procedure for the isolation and purification of substances based on preferred crystallization of one of the components from solutions or melts. The process involves several steps. At the first step the initial solution is divided into two fractions, the concentrate enriched in one of the components, and the tailings (a solution poor in that component). This is done

by a partial crystallization of the components induced by cooling, the addition of substances lowering the solubility of the components, or isothermal evaporation. At the next step, each of the two fractions is divided as before, and so on.

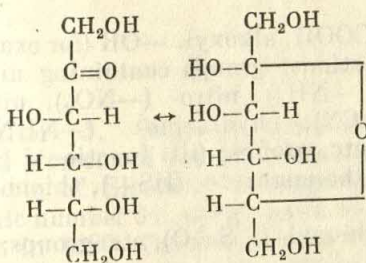
fractional distillation. A procedure for separating mixtures of liquids into fractions with b.p.'s within certain temperature ranges by collecting the distillation products in a series of separate fractions.

fractional précipitation. A procedure for separating compounds having similar solubilities and chemical properties by precipitating the components in small portions (fractions).

francium (from France) Fr. A Group I radioactive element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 87. Discovered in 1939 by Marguerite Perey of the Curie Institute, Paris. The only natural and longest lived isotope is ^{223}Fr , $T_{1/2} = 21$ min. A typical alkali metal, the closest analogue of cesium.

Freon [The first letter from fluorine + *re* from refrigerant + *on*]. Trademark for a line of fluorinated and fluorochlorinated hydrocarbons used as refrigerants. Made by the action of hydrogen fluoride on the corresponding hydrocarbons. Practically harmless. The most common marks are Freon-12 (CCl_2F_2) and Freon-11 (CCl_3F) used in home refrigerators, etc.

fructose (fruit sugar) $\text{C}_6\text{H}_{12}\text{O}_6$. A monosaccharide (see *carbohydrates*) occurring naturally in a large number of fruits (apple, tomato) and in honey. A constituent of saccharose. A hydroxyketone existing in two forms, the ketone and the cyclic one:



Oxidized only with difficulty to two hydroxyacids, a weaker reducing agent than glucose. Prepared by the

hydrolysis of saccharose and polysaccharides. Easily assimilated by organisms.

fruit sugar. See *fructose*.

fuchsin $C_{20}H_{20}N_3Cl$. A synthetic rosaniline dyestuff, a mixture of rosaniline and pararosaniline hydrochlorides. Green crystals with bronze lustre, aqueous solutions are purple red. A dye unstable in the light. Used in the manufacture of some acidic dyes.

fuel cell. A chemical source of current in which energy evolved during combustion of a fuel (hydrogen, alcohols, aldehydes, etc.) is transformed directly into electric energy. Used in spaceships, internal combustion engines, warfare.

fuel for internal combustion engines: gasoline, diesel oil, motor benzol, etc.

fumigant. A substance used to fumigate plants in order to kill vermins and destroy bacteria causing plant diseases by poisonous vapours and gases, e.g. chloropicrin, dichloroethane, various mixtures (CS_2 with CCl_4 , SO_2 with formalin, etc.).

fumigating. Killing pests by exposing them to the action of fumes of certain chemical substances such as chloropicrin, dichloroethane, and various mixtures (CS_2 and CCl_4 , SO_2 and formalin, etc.).

functional analysis. A combination of physical and chemical methods for qualitative and quantitative determination of reactive atoms or groups of atoms (functional groups) in organic compounds. More than one hundred of functional groups are known, e.g. (i) functional groups containing

oxygen such as hydroxyl, $-OH$, carbonyl, $\begin{array}{c} \diagup \\ C=O \\ \diagdown \end{array}$,

carboxyl, $-COOH$, alkoxyl, $-OR$ (for example $-OCH_3$),

etc.; (ii) functional groups containing nitrogen such as

the amino- ($-NH_2$), nitro- ($-NO_2$), nitroso- ($-NO$),

nitrilo- ($-CN$), hydrazino- ($-NHNH_2$), amido-

($-CONH_2$), etc. groups; (iii) functional groups contain-

ing sulphur: the mercapto- ($HS-$), thiono- ($=S$), dithio-

($-S-S-$), thionyl- ($\begin{array}{c} \diagup \\ S=O \\ \diagdown \end{array}$), etc. groups; (iv) functional

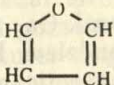
groups containing unsaturated carbon-carbon bonds:

$-C=C-$, $-C\equiv C-$. Functional analysis is applied to

determine the structure of unknown organic substances, to analyze organic objects, in monitoring industrial processes.

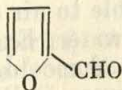
functional group. See *functional analysis*.

fungicide [fungus + *L caedere*, to kill]. Any substance that destroys fungi and their spores or inhibit their growth, used to protect growing plants (Bordeaux mixture, flowers of sulphur, etc.) or to treat seeds (formalin, Mercuriline, Granosan) in order to remove spores of fungal parasites, e.g. brand.

furan (furfuran, tetrol)  . A heterocyclic com-

pound containing oxygen in the five-membered ring. The simplest member of a large series of compounds having practical applications. See *furfural*.

furfural [*L furfur*, bran] (furfurol; ant oil, artificial)



An aldehyde of furan, a colourless sweet-smelling oily liquid, made from oat-hulls, rice-hulls, corn cobs by hydrolysis. Used in the manufacture of synthetic resins, divinyl, adhesives, as a solvent, etc.

fusel-oil. A mixture of alcohols from C_3H_7OH to $C_5H_{11}OH$, formed in alcoholic fermentation. Individual alcohols can be isolated from fusel-oil by distillation.

G

gadolinium (after J. Gadolin, Finnish chemist) Gd.

A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, belongs to the lanthanide series, atomic number 64, atomic mass 157.25. Discovered by Maignac in 1880. Oxidation state +3, forms oxide Gd_2O_3 . Gadolinium salts are colourless, gadolinium chloride, sulphate, nitrate, and acetate are soluble in water.

Uses: control of nuclear reactors.

galactose. A simple carbohydrate of the hexose series, $C_6H_{12}O_6$. Very soluble in water. Occurs in plants as constituent of carbohydrates, agar-agar, hemicellulose, and other polysaccharides. Contained in milk. Resembles glucose in its properties.

galena (galenite, lead glance) PbS . A mineral, lead sulphide. Contains Ag, Au, and a number of other elements as admixtures. Wide-spread. Colour lead grey, not transparent. The most important lead ore, also recovered for silver and gold.

gallium [*L. Gallia*, France]. Ga. A Group III element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 31, atomic mass 69.72, two stable isotopes, ^{69}Ga (60%) and ^{71}Ga (40%), has been predicted by Mendeleev as eka-aluminium (1870). Discovered by Lecoq de Boisbaudran in 1875.

Properties: silvery-white metal, m.p. $29.8^\circ C$, b.p. $2230^\circ C$. An analogue of aluminium, the oxidation state in compounds +3. Stable to air oxygen at room temperature, does not reduce water. Except for iodine, halogens react with gallium in the cold. Acids dissolve gallium at elevated temperatures. Gallium oxide, Ga_2O_3 , is a white substance. Gallium hydroxide, $Ga(OH)_3$, shows amphoteric properties.

Uses: gallium and its alloys are used in high-temperature thermometers, can replace mercury in vacuum pumps. Gallium glass has high reflectivity. Gallium alloys with zinc, bismuth, cadmium, lead, and mercury have practical applications. The compounds $GaAs$, GaP , and $GaSb$ are semiconductors.

galvanic cell (after L. Galvani, an Italian scientist). A chemical source of current in which electricity is produced by chemical action. A simple galvanic cell consists of two electrodes, a negative (e.g. Zn) and a positive one (e.g. Cu, metal oxides, carbon), placed into a solution of an electrolyte.

galvanization. A process for plating metals and non-metals with other metals by electrolysis.

galvanoplastics. The process for the preparation of metal duplicates of things by means of electrolysis.

gamma rays. Electromagnetic radiation with very short waves (below 0.1 nm) emitted by excited nuclei of atoms.

Originate in radioactive transformations of nuclei and in nuclear reactions. Unlike alpha and beta rays they do not deflect in electric and magnetic fields and are characterized by greater penetrating power. Used in flaw detection, etc.

garnet. Any of complex orthosilicate minerals, hardness 6.5-7.7 (depending on the composition).

Uses: the most important application is the manufacture of abrasives; also used in instrument manufacture (technical stones), in electronics (synthetic garnets), as substitutes for titanates in radar units and other microwave units. Intensely coloured garnets are used as jewellery.

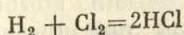
gas analysis. Analysis of mixtures of gases for the determination of their qualitative and quantitative compositions.

gasification of solid fuel. High-temperature conversion of solid fuel into gaseous fuel by means of partial oxidation under the action of oxygen, air, water vapour, and other gases. All kinds of solid fuel can be gasified including bituminous coal, lignite, anthracite, coke, peat, wood, oil-shale, etc.

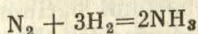
gasoline (petrol, motor spirits). A colourless or yellowish liquid, b.p. may range from 30 to 205 °C, density 0.700 to 0.780 kg/m³. The major components are hydrocarbons from C₅ to C₁₁. Produced from petroleum. Fuel for internal combustion engines, solvent.

Gay-Lussac law of combining volumes (Gay Lussac, 1808).

Gases combine in a simple ratio by volume to each other and to the gaseous products measured under the same conditions of temperature and pressure. For example, one volume of hydrogen combines with one volume of chlorine to give two volumes of hydrogen chloride:



One volume of nitrogen combined with 3 volumes of hydrogen to give 2 volumes of ammonia:



gel [*L. gelare*, to freeze]. A disperse phase having mechanical properties of a solid because of its structure. Gels are formed in coagulation of sols. Undergo irreversible destruction on drying.

gelatin [*L. gelare*, to freeze]. A mixture of animal proteins, contains 15% water and 1% ash; colour pale yellow.

Swells in water, dissolves in hot water to form a jellylike substance upon cooling which again becomes a solution when heated. Made from bones, cartilage, and skin of animals, or scales and swimming-bladders of fish. Used in the manufacture of photographic film and paper, confectionery, cookery, brewing, wine production, the paper industry, polygraphy, etc. Also used in microbiology to prepare nutrient media.

geochemistry. A branch of study dealing with the chemical composition of earth's crust and deeper parts, and the laws governing combination, distribution, and migration of chemical elements.

German silver. See *nickel silver*.

germanium [L *Germania*, Germany] Ge. A Group IV element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 32, atomic mass 72.59. Predicted and described by Mendeleev as eka-silicon (1871). Discovered by Winkler in 1886.

Properties: silver-grey, brittle, does not yield to either hot or cold work; m.p. 958 °C. The oxidation states +4, +2 (and -4); at high temperatures, readily undergoes oxidation in the air to give oxides, GeO and GeO₂; reacts with metals to form germanides which evolve germanium hydrides (GeH₄ etc.) under the action of HCl; easily combines with halogens; forms quite a number of organogermanium compounds.

Occurrence: found in a rare mineral argyrodite, 4Ag₂S · GeS₂, and in germanite, Cu₃(Ge, Fe)S₄, as admixture in zinc and tin ores.

Derivation: recovered from residues of zinc and tin ores.

Uses: a typical semiconductor, used in various electronic devices.

getter alloys. Substances used in vacuum tubes to absorb gases and vapours and to remove residual impurities. Metal powders (Ta, Ti, Ba, Zr, Nb, Ce, etc.) and various compositions (iron-barium, barium-aluminium-titanium, barium beryllate) are used for the purpose.

glass. A transparent amorphous alloy of various silicates with each other or with silica, made from white sand, soda, lime, and chalk. A mixture of these ingredients is heated in special furnaces by air gas. The properties of glass depend on its chemical composition, preparation conditions, and further processing.

glass fibre laminates. Products composed of glass or quartz fibre and a thermoplastic or thermosetting binding material. Are not inferior in strength to steel being 3 to 4 times lighter; used, e.g. in the manufacture of corrosion-resistant tubes which can stand high pressure. Employed in automobiles, aircraft, shipbuilding, and many other fields of industry.

glass filter. A porous glass disk or plate fused into a glass cylinder or funnel, widely employed for filtering.

glass, liquid. See *sodium silicate*.

glass, optic. Homogeneous transparent colourless materials of various chemical compositions, used in the manufacture of lenses, prisms, cells, etc. Classified as flint glass (contains 26 to 65% PbO , the rest SiO_2 and other oxides) and crown glass (contains 32 to 72% SiO_2 , the rest B_2O_3 and oxides of alkali metals and other elements).

glass, quartz. Glass containing not less than 99% quartz, made by fusing the purest natural varieties of quartz (rock crystal, vein quartz, quartz sand) at temperatures above 1700°C . Can stand very high temperatures, expands only insignificantly when heated, and is therefore employed as a material for laboratory glassware (crucibles, flasks, etc.) and in the chemical industry. Transmits UV radiation absorbed by ordinary glass and is used in optical instruments, mercury lamps.

glass, soluble. See *sodium silicate*.

glassware, chemical. Glassware of high chemical and thermal stability.

Glauber's salt (mirabilite) $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$. Natural sodium sulphate. First obtained by Glauber by the action of sulphuric acid on sodium chloride. Used in the manufacture of glass, soda production, in medicine.

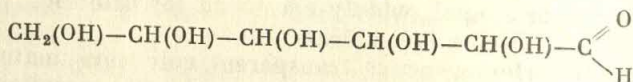
glaze. A vitreous solid solution containing silica, alkali metal aluminosilicates, and metal oxides. Used for coating ceramics. Coloured glazes contain cobalt, copper, chromium, manganese, iron, etc. salts or oxides; white glaze is made by the addition of 5 to 10% cryolite, tin(IV) oxide, or zirconium oxide.

globulin [L *globus*, a ball, sphere]. Any of a group of simple proteins which is insoluble in water, soluble in dilute solutions of neutral salts, weakly acidic. Globulins occur in all animal and plant tissue. Constitute the major

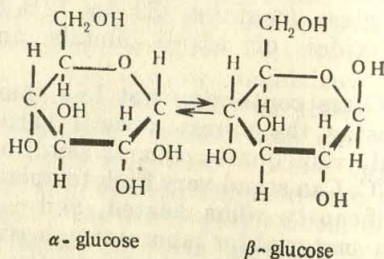
part of protein in many seeds, especially beans and oil-bearing crops.

glucoproteide. A complex protein, a compound of a protein and a carbohydrate; here belong many mucilages. When hydrolyzed give amino acids, carbohydrates and their derivatives, sometimes acids such as sulphuric, acetic, etc. Also spelt glycoproteide.

glucose [Gk *glykys*, sweet] $C_6H_{12}O_6$:



The most familiar monosaccharide of the hexose series.
May be cyclic



Contained in the free form in all green plants, especially in grapes. Occurs as a constituent in cellulose, starch, dextrins, maltose, and other carbohydrates. Found in small amounts almost in all man and animal organs and tissue. In liver, glucose is transformed into glycogen. Glucose is the end product of hydrolysis of disaccharides and polysaccharides.

Properties: can undergo reduction to a hexahydric alcohol; like all aldehydes readily undergoes oxidation; reduces silver from ammonia solution of silver oxide, and copper(II) to copper(I).

Derivation: hydrolysis of starch and cellulose (industrial method).

Uses: medicine, can be introduced into blood directly; confectionery; the production of ascorbic and gluconic acids.

glucosides. See *glycosides*.

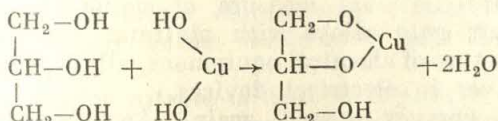
glue. A substance made of materials of animal origin and having a high adhesive power.

gunpowder, smokeless. An explosive with nitrocellulose as the major component.

glyceride. See *fats*.

glycerol $\text{HOCH}_2\text{—CHOH—CH}_2\text{OH}$. The simplest trihydric alcohol.

Properties: a colourless syrupy liquid, soluble in water, sweet taste. Reacts with copper hydroxide to give a transparent bright-blue solution of copper glycerate:



Esters of glycerol and organic fatty acids are fats.

Derivation: by the saponification of fats and synthetically.

Uses: medicine, the manufacture of leather, textile industry, printing, the production of plastics and nitroglycerol (an explosive).

glycine (α -aminoacetic acid, glycocoll). The simplest mono-amino carboxylic acid. All other monoamino carboxylic acids may be regarded as glycine derivatives where one of the glycine methylene hydrogens is replaced by some hydrocarbon radical. Glycine is one of the most widespread amino acids incorporated in proteins.

glycocoll. See *glycine*.

glycogen (animal starch, liver starch) $(\text{C}_6\text{H}_{10}\text{O}_5)_n$. A polysaccharide, the storage carbohydrate of the animal organism, found especially in the liver and muscle. Slightly soluble in cold water, forms a colloidal solution in hot water. Iodine turns glycogen brownish-red. Undergoes hydrolysis to give glucose.

glycol. A dihydric alcohol whose molecule contains two hydroxyl groups, e.g. ethylene glycol, $\text{HOCH}_2\text{CH}_2\text{OH}$. Shows all alcohol properties.

glycoproteide. See *glucoproteide*.

glycosides. A group of organic compounds incorporating a sugar (usually glucose) and some other than carbohydrate compound, e.g. an alcohol. Occur in many plants and often make them bitter, e.g. amygdalin.

gold Au. A Group I element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 79, atomic mass 196.967. One stable isotope, ^{197}Au .

Properties: a noble metal, yellow colour, very malleable

and ductile. Insoluble in alkalis and acids but dissolves in mixtures of HCl and HNO₃ (*aqua regia*), reacts with halogens; the oxidation states in compounds +1, +3; solutions of AuCl₃ in HCl contain complex ions [AuCl₄]-; gold compounds are unstable, readily undergo reduction to the metal, the most widespread and stable derivative is chlorauric acid, H[AuCl₄]·4H₂O.

Occurrence: found in nature in the free state.

Uses: international measure of value, jewellery and dentistry; gold alloys with platinum are used in the manufacture of chemical equipment, alloys with platinum and silver in electrical devices.

granite [L *granum*, a seed, grain]. An ingeneous rock of deep origin, composed of quartz, feldspar, plagioclase, and mica. Used in building cameras for the production of HCl and HNO₃, in building in general.

graphite [Gk *graphein*, to write]. A mineral, the crystalline allotropic form of carbon, unlike diamond relatively soft. Natural graphite contains admixtures in the amount of 10 to 12%. Colour grey, metallic sheen. Infusible, stable to heating in the absence of air. Used in nuclear reactors for decelerating neutrons, in metallurgy, in electrical technology, the manufacture of lubricants, electrodes, pencils, etc. Synthetic graphite is prepared by heating carbon (anthracite) to 2500 °C in an electrical furnace in the absence of air.

gravimetric analysis. The most important method of the quantitative chemical analysis where weighing is not only the first but also the last step of the procedure. Gravimetric analysis is based on the law of the preservation of mass in chemical transformations. The measurement instrument is an analytical balance. The results are usually expressed in per cent. Gravimetric analysis has played an important part in the establishing of the law of the constancy of the chemical composition of substances, the law of multiple proportions, the periodic law, etc. It is employed to determine the chemical composition of various objects (rocks and minerals), to control the quality of raw materials and goods, etc.

group of elements. See *Periodic Table of Elements* by D.I. Mendeleev.

group reagent. A reagent giving characteristic products with a large number of inorganic ions or certain classes

of organic compounds (precipitate, gas, soluble coloured substances). For example ammonium sulphide, $(\text{NH}_4)_2\text{S}$, is the group reagent for the cations Fe^{3+} , Mn^{2+} , Zn^{2+} , Al^{3+} , Cr^{3+} , Ni^{2+} , Co^{2+} , Be^{2+} , Ge^{4+} , Zr^{4+} , Th^{4+} , and VO_2^{2+} . With all of these it forms precipitates insoluble in water. Group reagents are used to isolate a group of ions from a mixture.

guanidine $(\text{NH}_2)_2\text{C}=\text{NH}$.

Properties: colourless deliquescent crystals. A strong monoacidic base, forms stable salts with HCl , HNO_3 , and H_2CO_3 .

Uses: guanidine nitrate is used as explosive, phosphate in the textile industry (fire-proofing), carbonate in the manufacture of surfactants. The product from the condensation of guanidine with formaldehyde is used as ion exchanger.

gutta-percha [Malay, *getah*, gum + *perca*, tree from which it is obtained]. A high-molecular-weight hydrocarbon, $(\text{C}_5\text{H}_8)_n$, close to rubber in its composition, an isoprene polymer and an isomer of natural rubber. Obtained from the milky juice of plants of Malaya and the Philippines. A leather-like material of white or yellowish colour; like rubber can be vulcanized by sulphur. Used in electric insulation, in the chemical industry, and in the manufacture of shoes.

gypsum. A natural hydrated calcium sulphate, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. At 107°C , partly loses water to become alabaster, $2\text{CaSO}_4 \cdot \text{H}_2\text{O}$. Noticeably soluble in water. Fibrous gypsum (selenite) is used in the manufacture of cheap jewellery. Other uses: the production of cement, fertilizers, paints, paper (as a filler). Calcined gypsum is used for moulding (bas-reliefs, cornices), as bonding material in building, and in medicine.

H

hafnium [L *Hafnia*, ancient name of Copenhagen] Hf.

A Group IV element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 72, atomic mass 178.49. Predicted by Mendeleev, discovered in 1923 by Coster and Hevesey in an ore from Norway.

Properties: a silvery-white metal, ductile, readily yields

to hot and cold work. An analogue of zirconium in its chemical properties. The oxidation state in compounds +4. In the air gets covered with an oxide film, HfO_2 . Reacts with halogens when heated; at high temperatures, reacts with nitrogen and carbon to give high-melting HfN and HfC . Dissolves in hydrofluoric and concentrated sulphuric acids. Aqueous solutions of hafnium salts readily undergo hydrolysis.

Occurrence: a typical scattered element: does not form minerals of its own, accompanies zirconium.

Uses: the manufacture of filaments, cathodes of vacuum tubes, heat-resistant iron and nickel alloys, in nuclear energy devices.

half-life ($T_{1/2}$). The time taken for the number of unstable particles to decrease by a factor of two; one of the most important characteristics of radioactive isotopes, unstable elementary (fundamental) particles.

halite. A mineral, natural sodium chloride, NaCl . Pure halite is colourless and transparent. Iron oxide admixtures make it yellow or red, clay grey, organic substances brown or black. Used in the manufacture of soda, sodium hydroxide, hydrochloric acid, sodium metal, chlorinated lime, etc.

halogenated hydrocarbons. Hydrocarbons with one or several hydrogen atoms replaced by halogens. Made by direct interaction of hydrocarbons (both saturated and unsaturated) with halogens. Used in the synthesis of many organic substances (alcohols, amines, etc.).

halogens [Gk *hals*, *halos*, salt + *genes*, born]. The chemical elements of Group VIIA of the Mendeleev Periodic Table of Elements: fluorine, F; chlorine, Cl; bromine, Br; iodine, I, and astatine, At. All halogens are strong oxidants. In passing from F to At, the reactivity of halogens decreases and that of halide ions, F^- , Cl^- , Br^- , I^- , increases. See *fluorine*, *chlorine*, *bromine*, *iodide*, *astatine*.

hard alloy. Hard and wearable metallic materials which retain their properties at 900-1000 °C. Most often contain tungsten and titanium carbides as the major components and varying amounts of cobalt. Used for tipping drill bits and cutting tools.

hardness, scale of. Mohs' scale, a scale suggested by Mohs in the 19th century for ordering materials according to their hardness; the ordering is based on the ability of

a harder material to scratch a softer one. The scale includes ten materials arranged in the order of increasing hardness, viz.

- | | | | |
|------------|---------------|-------------|-------------|
| 1. talc | 4. fluorite | 7. quartz | 10. diamond |
| 2. gypsum | 5. apatite | 8. topaz | |
| 3. calcite | 6. orthoclase | 9. corundum | |

hardness of water. The property of natural water caused by the presence of dissolved calcium and magnesium salts. The total content of these salts determines the total hardness of water which can be measured by titrating water with chelating agents. The total hardness includes the temporary hardness caused by the presence of the metal hydrocarbonates and the permanent hardness caused by the presence of the metal sulphates. The former can be decreased by boiling the water, while the latter cannot. All hardness can be removed by the use of zeolites.

heat of formation. The thermal effect of the reaction of the formation of a given substance from the elements in their normal state. Measured in joules.

heat transfer agents. Liquid or gaseous substances used for heating various devices, e.g. in the chemical industry. The most familiar heat transfer agents are water (below its boiling point), glycerol, petroleum oils, melts of metals (Sn, Pb, Na, K), superheated water vapour, air, nitrogen, etc.

helium [Gk *helios*, the sun] He. A Group VIII element of the 1st period of the Mendeleev Periodic Table of Elements, atomic number 2, atomic mass 4.0026. Natural helium contains two stable isotopes, ^3He and ^4He , the latter being by far more abundant. First isolated by Ramsay from the radioactive mineral, uraninite (1895). Properties: a monoatomic gas, chemically inert, colourless and odourless, b.p. -268.9°C . The helium atom consists of the nucleus and two electrons. The nucleus is very stable: it is formed in nuclear reactions. Occurrence: constitutes 0.0005% of earth's atmosphere, present in the atmospheres of the sun and stars. Formed and accumulated in radioactive minerals undergoing alpha-decay.

Derivation: from natural gases containing helium.

Uses: used in cyostats for deep cooling, as inert shield in metallurgy (arc welding) and scientific work, in nuclear

engineering. Liquid helium is a colourless fluid used in physicochemical experiments carried out at very low temperatures.

hematite. One of the chief ores of iron, Fe_2O_3 , widely distributed in nature. Colour black to dark-steel and cherry-red. Varieties: iron glance, red hematite, etc. Can be prepared synthetically.

Uses: smelting of pig iron, in the manufacture of lacquers and dyes as a mineral pigment (iron minium), as a pigment in oilcloth, linoleum, red pencils, polygraphy, stable coloured enamels. Also used for decorative purposes.

hemoglobin [Gk *haima*, *haimatos*, blood + *L globus*, a ball, sphere]. A red pigment of red blood corpuscles in man and animals, a complex protein carrying oxygen from respiratory organs to tissue.

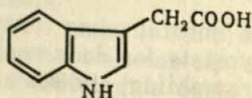
heptane $\text{CH}_3(\text{CH}_2)_5\text{CH}_3$. A saturated hydrocarbon of the alkane series; a colourless mobile liquid with a weak odour, b.p. 98.4°C , density 0.684 kg/l (20°C). Used as a standard for measuring the degree of knocking of light motor fuels, its octane number is taken to be 0.

herbicide [*L herba*, grass + *caedere*, to kill]. A weed-killer, can be of general and specific action. Weed-killers of general action destroy all plants including small trees, bushes, grass. Other herbicides suppress growth of some plants being harmless to other plants when introduced in due amounts. The latter are used to destroy weeds in agriculture. In recent years phenoxyacetic acid and its derivatives such as 2,4-dichlorophenoxyacetic acid have been used extensively; these substances suppress weeds but do not have any appreciable action on corn. Some herbicides, e.g. 2,4-dichlorophenoxyacetic acid, stimulate growth of plants when used in small doses.

Hess law (1840). The amount of heat evolved in some chemical process is always the same irrespective of whether the process goes as a one- or many-step reaction. The total thermal effect is independent of the intermediate stages of a system but only depends on its initial and final states.

hetero atoms. See *heterocyclic compounds*.

heteroauxin (3-indoleacetic acid, beta-indoleacetic acid)



An auxin, used to promote growth in plants.

heterocyclic compounds. Cyclic organic compounds containing alongside carbon, atoms of other elements in the rings; these atoms are called hetero atoms. Typical hetero atoms are: oxygen (in furan and pyran), nitrogen (in pyrrole and porphyrins, indole, pyrazole, pyridine, pyrimidine, quinoline, isoquinoline, purine, etc.), sulphur (e.g. in thiophene), selenium (e.g. in selenophene), etc. Heterocyclic compounds can contain two different hetero atoms, e.g. thiazole. Heterocyclic compounds of the pyrrole series (hemoglobin, chlorophyll), pyrone series (vegetable pigments), pyridine, quinoline, and isoquinoline series (various alkaloids), purine series (uric acid, caffeine, etc.), thiophene series (petroleum) are widely distributed in nature. Some heterocyclic compounds are obtained from coal tar (pyridine, quinoline, acridine, etc.) and from plants (furfural). Many natural and synthetic heterocyclic compounds are valuable dyes (indigo), pharmaceuticals (quinine, morphine, mepacrine, aminophenazone). Used in the manufacture of plastics, as accelerators of rubber vulcanization, and in the manufacture of photographic materials.

heterogeneous systems. Systems comprising several homogeneous parts (phases) separated by interfaces. Phases can differ from each other in their compositions and properties. Examples of heterogeneous systems are: water—saturated vapour; a saturated solution over a precipitate; many alloys. A solid catalyst in a gas flow or in a liquid is also a part of a heterogeneous system (heterogeneous catalysis).

hexachlorocyclohexane (benzene hexachloride) $C_6H_6Cl_6$. A mixture of 8 stereoisomers of 1,2,3,4,5,6-hexachlorocyclohexane. All the isomers are white, crystalline substances, insoluble in water. Has a limited application as a pesticide.

hexadecane (cetane) $CH_3-(CH_2)_{14}-CH_3$. An acyclic saturated hydrocarbon with a normal (nonbranched) structure, an ideal Diesel fuel, used as a standard in estimating the quality of Diesel fuels (the cetane number is a rating for Diesel fuel like the octane number for gasoline).

hexamethylenediamine (1,6-hexanediamine*) $NH_2(CH_2)_6NH_2$. A colourless crystalline solid, very soluble in organic solvents, forms salts with inorganic and carboxylic acids.

Hexamethylenediamine salts of carboxylic acids give the corresponding amides upon heating, which property is utilized in the manufacture of polyamide high polymers, especially nylon.

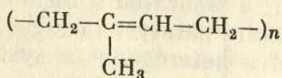
hexamethylenetetramine. See *methenamine*.

hexamine. See *methenamine*.

hexose $C_6H_{12}O_6$. Any of monosaccharides containing 6 carbon atoms, e.g. glucose and fructose; differ in their abilities to be assimilated in man. Some hexoses are formed in the decomposition of more complex carbohydrates. All hexoses can participate in fermentation processes, e.g. alcoholic and lactic fermentation. See *carbohydrates*.

high-melting metals. Metals of Groups V and VI of the Mendeleev Periodic Table of Elements, viz. W (m.p. $3410^\circ C$), Ta ($2996^\circ C$), Mo ($2622^\circ C$), and Nb ($2500^\circ C$); have wide technical applications.

high-molecular-weight compounds. Chemical compounds with molecular masses of several thousand to several million. The atoms of high-molecular-weight compounds are linked with each other by chemical bonds. The atoms or atomic groups either form linear chains (linear high polymers, e.g. cellulose) or branched chains (branched high polymers, e.g. amylopectin). High-molecular-weight compounds containing a large number of recurring units in their molecules are called *polymers*, e.g. polyvinyl chloride, $(-CH_2-CHCl-)_n$, natural rubber



Compounds whose molecules contain recurring groups of several types are called **copolymers**. High-molecular-weight compounds have valuable properties and are used in mechanical engineering, the textile industry, agriculture and medicine, aircraft, shipbuilding, in household (textile, imitations of leather, ware, glues, lacquers, decorative articles, etc.). They are also used in the manufacture of rubber, fibre, plastics, films, lacquers, and dyes for coatings. All tissues of living organisms are high-molecular-weight substances.

holmium [L *Holmia*, Latinized form of Stockholm) Ho. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 67, atomic

mass 164.93; a lanthanide. Discovered in 1879 by Cleve. The oxidation state in compounds +3. Holmium oxide and holmium salts are yellow.

homogeneous system. A physicochemical system containing a single phase; in homogeneous systems comprising two or more chemical components each of the components is distributed in the bulk of the other compound in the form of molecules, atoms, or ions. The components of a homogeneous system cannot be separated by mechanical means. All the physical characteristics of a homogeneous system have the same values over the system or vary continuously from one point to another. Examples: ice, liquid or solid solutions, mixtures of gases.

homologous series. A series of related organic substances with similar properties whose molecules differ from each other by one or several CH_2 groups. For instance, the homologous series of saturated hydrocarbons (the methane series) has the general formula $\text{C}_n\text{H}_{2n+2}$ and includes methane, CH_4 , ethane, C_2H_6 , propane, C_3H_8 , etc. Compounds of a series are characterized by reactions typical for the functional group(s) contained in all series members. The physicochemical properties of homologues vary smoothly with an increase in their molecular masses.

homopolar bond. A type of a chemical bond. See *covalent bond*.

hopcalite. A mixture of MnO_2 and CuO , sometimes contains $\text{Co}_2\text{O}_3 + \text{Ag}_2\text{O}$. Used in gas masks as a catalyst of the oxidation of carbon monoxide to carbon dioxide by air oxygen.

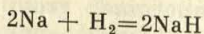
hormone [Gk *hormaein*, to stimulate, excite]. A biologically active substance produced in small amounts in organisms and controlling metabolism. In man and animals, hormones are formed by the internal secretion of ductless or endocrine glands (thyroid, suprarenal glands, pancreas, hypophysis, etc.) and carried by blood or tissue fluid. An increase or a decrease in hormone production causes endocrinic diseases; the production of hormones by endocrine glands is controlled by the nervous system. Plant hormones include e.g. auxines. More than 30 hormones and many hormone-like substances are known.

hydration [Gk *hydor*, water]. The addition of water to molecules or ions, a particular case of *solvation* (the addition

of organic solvent molecules). Unlike hydrolysis does not cause the formation of hydrogen or hydroxyl ions. Results in the formation of stable or unstable compounds of water with a solute (hydrates); in organic solvents, various solvates are formed. Hydration is responsible for the stability of ions in aqueous solutions; it impedes the association of ions.

hydrazine (diamine) $\text{H}_2\text{N}-\text{NH}_2$. A colourless, highly hygroscopic liquid, gives basic aqueous solutions. A strong reducing agent. Numerous organic derivatives of hydrazine are known. Hydrazine salts are colourless, mostly very soluble in water; the most important one is hydrazine sulphate, $\text{N}_2\text{H}_4 \cdot \text{H}_2\text{SO}_4$. Used in the organic synthesis, in the manufacture of plastics, rubber, insecticides, explosives, as a component of rocket fuels. Hydrazine and its derivatives are strong poisons.

hydride. A compound of hydrogen with an element: the term is largely used with reference to metal compounds. Hydrides are made from a metal and hydrogen at definite temperature and pressure:



Volatile hydrides are formed by boron and Group IVA, VA, VIA, and VIIA elements (e.g. B_2H_6 , SiH_4 , GeH_4); they are isolated from reactions between the elements and hydrogen or by hydrolyzing element compounds with metals under the action of water or acids. Used in the manufacture of some pure metals and in the organic synthesis.

hydrocarbon. A compound of carbon and hydrogen; hydrocarbons are classified as saturated, unsaturated, alicyclic, and aromatic compounds. Acyclic saturated hydrocarbons contain only single carbon-carbon bonds (the methane series, alkanes). Acyclic unsaturated hydrocarbons may contain one double bond (the ethylene series, alkenes), one triple bond (the acetylene series, alkynes), two double bonds (dienes), etc. Cyclic saturated compounds include such species as naphthenes (polymethylenes). Aromatic hydrocarbons of the benzene series containing three double bonds may serve as examples of unsaturated cyclic hydrocarbons.

hydrocarbonate. An acid salt of carbonic acid. Hydrocarbonates of practical utility are ammonium hydrocarbon-

ate, NH_4HCO_3 , a nitrogen fertilizer; sodium hydrocarbonate, NaHCO_3 , used in medicine, baking (baking soda).

hydrochemistry. The study of the chemical composition of natural waters and of its variations depending on various chemical, physical, and biological processes.

hydrochloric acid (muriatic acid). An aqueous solution of hydrogen chloride, HCl .

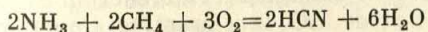
Properties: a strong monobasic volatile acid with a pungent odour; admixtures of iron and chlorine make it yellowish. Commercial concentrated hydrochloric acid contains 37% HCl , density 1.19. Easily reacts with metals, metal oxides, metal hydroxides, and salts. Metal salts of hydrochloric acid, metal chlorides, are very soluble in water except for AgCl and Hg_2Cl_2 .

Derivation: by the dissolution in water of hydrogen chloride made from chlorine and hydrogen or by the action of sulphuric acid on sodium chloride.

Uses: the manufacture of various chlorides, organic dyes, metal cleaning, the removal of scale from boilers, cleaning of oil-wells; also used in the leather and food industries, medicine, etc. Plays an important part in digestion processes. See *hydrogen chloride*.

hydrocyanic acid (prussic acid) HCN .

Properties: a colourless liquid with a bitter almond odour, very volatile, b.p. 26°C , lighter than air in the vapour state. An unstable compound. Made by the oxidation of a mixture of ammonia and methane in the presence of platinum as catalyst:



A very weak monobasic acid. The acid and its salts are strong poisons, should be handled very carefully.

Occurrence: found as amygdalin in apple seeds, in cherry and plum seeds.

Uses: as a starting material for the synthesis of valuable high polymers (acrylonitrile and methacrylate polymers, copolymers of butadiene and styrene, etc.). Free acid is used as an insecticide and rodent poison. Salts of hydrocyanic acid are called cyanides; potassium cyanide, KCN , is used for extracting gold and silver from their ores, in the organic synthesis, in photography

hydrofluoric acid. An aqueous solution of HF.

Properties: reacts with many metals with the evolution of hydrogen (lead remains unattacked because of the formation of insoluble PbF_2 on its surface; gold and platinum are also insoluble in hydrofluoric acid). Like hydrogen fluoride, hydrofluoric acid destroys glass and other silicate materials by reacting with their principal component, SiO_2 : $4\text{HF} + \text{SiO}_2 = \text{SiF}_4 + 2\text{H}_2\text{O}$. Does not attack paraffin which is therefore used for storing the acid. Exceedingly poisonous, causes serious burns.

Uses: in the manufacture of organofluorine compounds, inorganic fluorides, lubricants, and plastics, for dissolving silicates in various analyses.

hydrogen [Gk *hydor*, water + *genes*, born] H. The first element of the Mendeleev Periodic Table of Elements, atomic mass 1.00797. Discovered in 1766 by Cavendish. Contains three isotopes, protium (^1H), deuterium (D or ^2H), and tritium (T or ^3H). The hydrogen atom contains one electron, the molecule two atoms linked by a covalent bond.

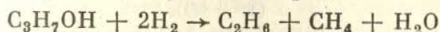
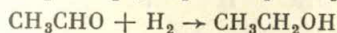
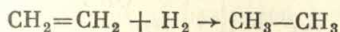
Properties: a gas, the oxidation states in compounds +1 and -1. An effective reducing agent. Not very reactive under usual conditions, combines directly only with the most active non-metals (with fluorine; with chlorine reacts in the light). At elevated temperatures, reacts with many elements. The reaction with fluorine develops as explosion, with chlorine and bromine goes in the light or under heating, with iodine only at elevated temperatures. Combines with nitrogen in the presence of a catalyst to give ammonia. The reaction of hydrogen with carbon monoxide, CO, is of practical importance as a route to hydrocarbons, alcohols, aldehydes, etc. Combines directly with alkali and alkaline earth metals to produce metal *hydrides* (NaH , CaH_2 , etc.).

Occurrence: widely distributed in nature, constitutes 1% of the mass of earth's crust. The most abundant element in the universe, prevails in the sun and most stars constituting up to one half of their mass.

Uses: the synthesis of NH_3 , HCl, methanol manufacture (in the reaction with CO), welding and cutting metals, the hydrogenation of solid and liquid fuels, fats, and various organic substances, etc. Deuterium and tritium are used in the nuclear industry.

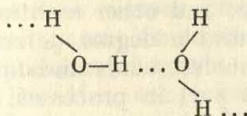
hydrogen antimonide. See *stibine*.

hydrogenation. The addition of hydrogen in the presence of a catalyst:



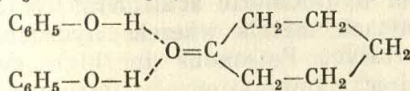
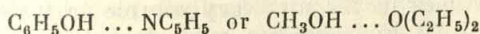
The elimination of hydrogen from various substances is called dehydrogenation; the two processes occur in dynamic equilibrium with each other. The most important industrial hydrogenation processes are the synthesis of ammonia, methanol (from CO and H_2), fats, and liquid fuels. The reaction is catalyzed by Ni, Pt, Co, Fe, Pd, Cu, V, etc.

hydrogen bond, a linking of two atoms of different molecules or of two atoms of the same molecule through the hydrogen atom. For example in water, the hydrogen atoms forming covalent bonds with oxygen react with oxygen atoms of neighbouring water molecules

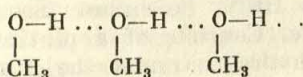


The interaction involves lone pairs on oxygen. Several types of hydrogen bonds (H-bonds) are known, e.g.:

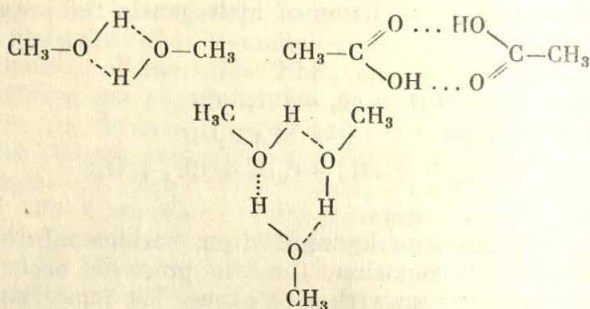
(1) intermolecular H-bonds,



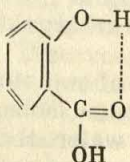
(2) chain (polymer) H-bonds,



(3) cyclic intermolecular H-bonds,



(4) intramolecular H-bonds,



H-bonding results in the association of molecules in alcohols, water, organic acids, etc., determines the properties of aqueous and other solutions, some polymers, etc., to a considerable degree determines the structure of proteins and nucleic acids and for that reason, plays a very important part in processes in vivo.

hydrogen bromide HBr. A compound of bromine and hydrogen. A colourless gas, strongly fumes in the air. Formed in the reaction of bromine vapour with hydrogen at a high temperature. Used in the manufacture of bromides, the bromination of organic substances.

hydrogen chloride HCl. A colourless gas with a pungent odour, fumes in the air, very soluble in water with the formation of hydrochloric acid. Dry hydrogen chloride does not attack metals whereas hydrochloric acid is highly corrosive. Poisonous in high concentrations. Made by direct combination of chlorine with hydrogen: $\text{H}_2 + \text{Cl}_2 = 2\text{HCl}$, or by the exchange reaction: $2\text{NaCl} + \text{H}_2\text{SO}_4 = 2\text{HCl} + \text{Na}_2\text{SO}_4$. The chief use is hydrochloric acid manufacture.

hydrogen cyanide HCN. Poisonous. See *hydrocyanic acid*.

hydrogen electrode. Consists of a platinum plate or wire saturated by hydrogen under the atmospheric pressure

and placed into a solution containing hydrogen ions. The platinum potential depends on the concentration of H^+ ions in the solution. On its surface, the reversible reaction $2H^+ + 2e \rightleftharpoons H_2$ occurs. Used for measuring the concentration (activity) of hydrogen ions.

hydrogen fluoride HF.

Properties: a colourless gas above $19.5^\circ C$, a mobile liquid below that temperature; very soluble in water, forms hydrofluoric acid in aqueous solutions. Poisonous.

Derivation: by the reaction $CaF_2 + H_2SO_4 = 2HF + CaSO_4$.

Uses: in the manufacture of cryolite, uranium fluoroderivatives, Freons, organofluorine compounds, for etching and frosting of glass.

hydrogen iodide HI. A colourless suffocating gas, strongly fumes in the air. Its solution in water is called hydriodic acid which is a colourless liquid with a pungent odour, a strong acid. Hydrogen iodide is an effective reducing agent. Used as a reagent in laboratory work and for the preparation of various compounds containing iodine.

hydrogen ion concentration. See pH.

hydrogen peroxide H_2O_2 .

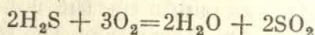
Properties: a colourless viscous liquid with a metallic taste, miscible with water. Very pure hydrogen peroxide is stable; in the presence of traces of heavy metals and their ions (Cu, Fe, Mn, etc.) decomposes: $2H_2O_2 = 2H_2O + O_2$. Can act as a reducing agent and as an oxidant; oxidizes metal nitrites to metal nitrates, the iodide ion to iodine, splits unsaturated hydrocarbons at the double bonds; reduces gold and silver salts, potassium permanganate in acid media. Concentrated solutions of hydrogen peroxide have a burning action on skin.

Uses: bleaching of wool, silk, wood pulp, etc. Used in the analytical chemistry, medicine, for the production of foam in the manufacture of various porous materials. Because of its strong oxidizing action used in rocket engineering.

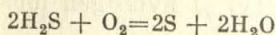
hydrogen sulphide H_2S .

Properties: a colourless gas with a characteristic disagreeable odour, heavier than air, slightly soluble in water (aqueous solutions turn turbid in the air because of the evolution of sulphur). Poisonous. Mixtures with air are dangerously explosive. Burns in the air with a

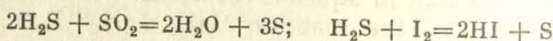
blue flame:



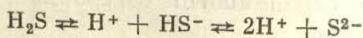
or, in the absence of sufficient oxygen:



(this reaction is used in sulphur manufacture). Hydrogen sulphide is a strong reducing agent:



Aqueous H_2S has a weakly acid reaction; it is a weak dibasic acid:

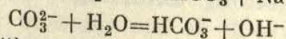
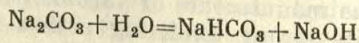


Occurrence: in volcanic gases, petroleum gas, mineral springs, formed in the denaturation of proteins.

Uses: metal salts of hydrosulphuric acid, metal sulphides, have important industrial applications. Hydrogen sulphide is used in the manufacture of sulphuric acid, free sulphur, metal sulphides, in the organic synthesis (the manufacture of thiophene and mercaptans), in the analytical chemistry for separating elements by precipitating their sulphides.

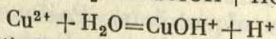
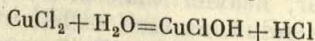
hydrolase. Any of enzymes catalyzing the hydrolysis of complex organic substances into simpler ones; usually, they split carbon-oxygen (in fats and carbohydrates) or carbon-nitrogen (in proteins) bonds.

hydrolysis [Gk *hydor*, water + *lysis*, loosening]. The interaction of substances with water with the formation of various compounds (acids, bases, etc.). Compounds that undergo hydrolysis include salts, carbohydrates, proteins, esters, fats, etc. The hydrolysis of salts has been studied in more detail than with other classes of substances. The hydrolysis of a salt of a weak acid and a strong base:



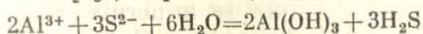
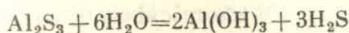
(the resulting solution is basic)

The hydrolysis of a salt of a strong acid and a weak base:



(the resulting solution is acid)

The hydrolysis of a salt of a weak acid and a weak base:

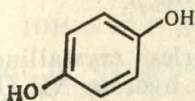


(the salt is hydrolyzed practically completely)

Salts of strong acids and strong bases do not undergo hydrolysis, and their solutions are neutral. Hydrolysis is a very important process. The hydrolysis of fats in the presence of alkalis gives soaps; the same process in the presence of catalysts is used to prepare glycerol and fatty acids.

hydrophilic, hydrophobic [Gk *hydor*, water + *philos*, loving/ *phobos*, a fear]. The characteristics of the intensity of the molecular interaction of the surface of bodies with water; refer not only to the properties of surfaces but also to separate molecules, groups of molecules, atoms, ions. Hydrophilic (wetable with water) substances have ionic crystal lattices (e.g. oxides, hydroxides, silicates, sulphates, phosphates, clays) or contain polar groups such as $-\text{OH}$, $-\text{COOH}$, or $-\text{NO}_2$. Hydrophobic substances (those that are not wetted by water) include most organic substances with hydrocarbon radicals, metals, semiconductors, etc. The terms lyophilic and lyophobic can be used to characterize the interaction of bodies with arbitrary solvents.

hydroquinone (1,4-benzenediol*, para-dihydroxybenzene). A



dihydric phenol, easily undergoes oxidation (reduces silver salts in the cold). Used in photography as a developer, in the synthesis of organic dyes as an antioxidant, etc.

hydrosulphate. An acid salt of sulphuric acid; hydrosulphates isolated in the solid state include alkali metal salts such as sodium hydrosulphate, NaHSO_4 .

hydrosulphite. An acid salt of sulphurous acid, e.g. sodium hydrosulphite, NaHSO_3 . All metal hydrosulphites are very soluble in water, many of them exist only in solutions. Alkali metal hydrosulphites have only been isolated.

hydroxide. A compound of an element oxide with water. Hydroxides of almost all chemical elements are known; some of them occur in nature as minerals. Metal hydroxides soluble in water are bases, e.g. $\text{Ca}(\text{OH})_2$, KOH , NaOH . Non-metal hydroxides are oxygen-containing acids, e.g. HNO_3 , H_2SO_4 , and H_2SO_3 . Hydroxides that can act as bases or acids depending on the conditions are called amphoteric hydroxides, e.g. $\text{Al}(\text{OH})_3$. The term hydroxides is often used only with reference to basic and amphoteric hydroxides.

hydroxonium H_3O^+ . A complex ion, a compound of proton

and water: $\left[\begin{array}{c} \text{H}^+ \\ | \\ :\text{O}-\text{H} \\ | \\ \text{H} \end{array} \right]^+$. Hydrogen ions occur in aqueous

or alcoholic solutions as hydrated or solvated hydroxonium ions.

hydroxyacid. An organic compound containing both the carboxyl and hydroxyl groups, e.g. lactic acid, $\text{CH}_3-\text{CH}(\text{OH})-\text{COOH}$. Hydroxyacids show properties typical for acids (dissociate, form salts, esters) and alcohols (undergo oxidation, form ethers, etc.). Widely distributed in nature. See *malic acid*, *lactic acid*, *tartaric acid*, *citric acid*.

hydroxy group (hydroxyl) OH . The water residue.

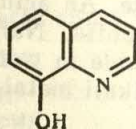
hydroxyl. See *hydroxy group*.

hydroxylamine NH_2OH .

Properties: a colourless crystalline solid, very soluble in water, forms the hydrate $\text{NH}_2\text{OH} \cdot \text{H}_2\text{O}$. Reacts with aldehydes and ketones to give oximes, $\text{R}-\text{CH}=\text{NOH}$ and $\text{R}_2-\text{C}=\text{NOH}$. The most important derivatives is hydroxylamine hydrochloride, $\text{NH}_2\text{OH} \cdot \text{HCl}$.

Uses: the hydrochloric salt is used in the inorganic analysis, for the determination of formaldehyde, furfural, camphor, glucose, in photography and medicine, in the organic synthesis.

8-hydroxyquinoline (8-quinolinol)



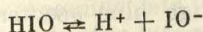
One of the commonest reagents in the analytical chemistry and radiochemistry used for separating and determining a number of metal ions which form chelate compounds with it. 8-Hydroxyquinoline and its derivatives are also used as fungicides and antiseptics.

hygroscopic [Gk *hygros*, wet, moist + *skopien*, to see]. Attracting moisture from the air. Examples of hygroscopic substances are anhydrous calcium chloride, concentrated sulphuric acid, phosphoric oxide.

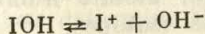
hypochlorite. A salt of hypochlorous acid, HClO , e.g. calcium hypochlorite, $\text{Ca}(\text{ClO})_2$. Used for bleaching in the textile, paper, cellulose industries, for destroying stable war gases (degassing), disinfecting drinking water and sewage, etc. See also *chlorinated lime*.

hypochlorous acid HClO . A weak monobasic acid, its solution can be prepared by the action of chlorine on water. Hypochlorous acid is unstable: $2\text{HClO} = 2\text{HCl} + \text{O}_2$. This reaction explains the strong oxidizing action of the compound. Its metal salts, hypochlorites, are used as oxidants, for bleaching fabrics, cellulose, paper, disinfecting water. See *Javelle water*, *chlorine water*, *chlorinated lime*.

hypoiodous acid HIO . Exists only in very dilute solutions. Dissociates as an acid



and a base



hypophosphite. A salt of hypophosphorous acid, H_3PO_2 .

hypophosphorous acid H_3PO_2 . A strong monobasic acid.

Its salts, hypophosphites, are used as reducing agents, in the manufacture of pharmaceuticals.

hyposulphite. Formerly, sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

I

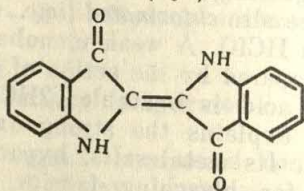
identification. Identifying of an unknown substance with a known one by comparing the physicochemical constants, properties, reactions of the two substances. Prior to identification substances are thoroughly purified and subjected to a preliminary examination which involves comparison of the states of aggregation, colours, viscos-

ities, solubilities in water and organic solvents, bases, and acids, flammabilities, and other properties.

imide. A compound containing the imide group, $>\text{NH}$, e.g. lead imide, PbNH , acetimide (imide of acetic acid), $(\text{CH}_3\text{CO})_2\text{NH}$. Unlike amides, imides of acids are weak acids rather than bases. Organic imides are widely applied in the synthesis of heterocyclic compounds, amines, amino acids, and peptides.

indicator. Any organic or inorganic substance which changes its colour depending on the hydrogen ion concentration (the pH value). Examples of acid-base indicators are methyl orange, phenolphthalein, and litmus.

indigo [Gk *indikon*, Indian (dye)].



Blue crystals, slightly soluble in most organic solvents. Used as a dye. The sulphonation of indigo yields indigo carmine used as a redox indicator, in the manufacture of ink and water paints.

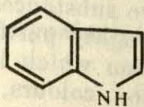
indium (from its indigo blue spectrum) In. A Group III element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 49 atomic mass 114.82, two stable isotopes, ^{113}In (4.33%) and ^{115}In (95.67%). Discovered in 1863 by Reich and Richter in zinc blende. The spectrum of indium contains intense blue lines whence its name. Was predicted by D.I. Mendeleev. A scattered element.

Properties: silvery white colour, m.p. 156°C . An analogue of gallium, the oxidation state +3; forms In_2O_3 upon heating in the air; dissolves in strong acids.

Derivation: certain lead, zinc, and tin ores are recovered for indium whose content there ranges from 0.001 to 0.1%.

Uses: corrosion-resistant coatings, low-melting alloys; indium compounds have semiconducting properties.

indole



. An organic heterocyclic compound.

Contained in bituminous coal tar, in some essential oils such as jasmine oil. Used as a starting material for the synthesis of heteroauxin and tryptophan, in the manufacture of perfumes and pharmaceuticals.

inert gas (noble gas, rare gas). Any of Group VIII elements of the Mendeleev Periodic Table of Elements, i.e. helium, He, neon, Ne, argon, Ar, krypton, Kr, xenon, Xe, or radon, Rn. In nature, inert gases are formed in various nuclear reactions. Constitute some 1% of the atmosphere. Inert gas atoms have stable outer electron shells, a two-electron (He) or an octet (all the other inert gases) shell. This explains their low reactivities. At present, a number of inert gas compounds have, however, been obtained. These are mostly compounds of krypton and xenon with water, fluorine, oxygen, and organic substances. The name 'inert' is therefore not very accurate. Inert gases are used for filling various lamps, in vacuum systems, in electronics, as inert gas shields in various processes.

infrared spectroscopy. Spectroscopy in the region of infrared radiation with wavelengths ranging from the limit of the red end of the visible spectrum, about 740 nm, to about 1 mm. Infrared spectra are employed to determine molecular structures of various organic and inorganic substances such as antibiotics, enzymes, alkaloids, polymers, complex compounds, etc. The number and positions of infrared bands give information about the nature of the compound (qualitative analysis), and band intensities can be used to determine the concentration (quantitative analysis). Infrared spectra are obtained using infrared spectrometers of various designs.

inhibitor. A general term for compounds that have the effect of slowing down a chemical change such as oxidation, polymerization, corrosion, etc. For example, hydroquinone inhibits the oxidation of benzaldehyde, technetium compounds inhibit corrosion of steel.

inorganic chemistry. The science of chemical elements and their compounds (carbon compounds except for the simplest ones are studied by the organic chemistry). The inorganic chemistry is based on the periodic law. The major tasks of the inorganic chemistry are the determination of the structure of atoms of elements and a thorough investigation of element properties as depending on their atomic structure, the study of the composi-

tion and properties of substances and the determination of their molecular structures, the development of methods for the synthesis of new materials with intended properties.

insecticide [L *insectum*, insect + *caedere*, to kill]. Any substance used to kill insects, e.g. organochlorine (dichlorodiphenyl-trichloroethane, DDT; benzene hexachloride), organophosphorus (parathion, demeton-O-methyl, malathion) compounds, arsenic derivatives (calcium and sodium arsenites, calcium arsenate), sulphur compounds, mineral oils, vegetable poisons containing alkaloids (anabasine, nicotine, etc.).

instrumental methods of analysis. Quantitative analytical procedures involving the use of electrochemical, optic, radiochemical, etc. instruments. The term is usually applied to (i) electrochemical methods such as potentiometry, polarography, conductometry, etc.; (ii) methods based on emission or absorption of light: emission spectral analysis, photometric techniques, X-ray spectral analysis; (iii) mass spectrometry; (iv) methods based on measurements of radioactivity. There are also other instrumental methods of analysis.

insulin [L *insula*, island, after the islands of Langerhans in the pancreas]. The pancreatic hormone of the protein nature, controls metabolism of carbohydrates and maintains the normal amount of sugar in the blood. Insulin is a simple protein, forms large associate particles in aqueous solutions. Used in treatment of diabetes mellitus, some types of mental disorders.

intermetallic compounds. Compounds of metals with metallic type bonding; do not conform to the laws of constant composition and multiple proportions.

intermolecular interactions. Repulsive or attractive interactions between electrically neutral particles, weak interactions called van der Waals interactions (after the Dutch physicist). Cause deviations from the ideal gas laws, explain the formation of molecular crystals, etc.

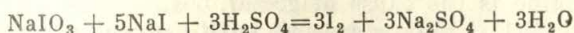
irreversible reaction. A complete transformation of starting materials into reaction products which are unreactive under given conditions, e.g. the decomposition of explosives, combustion of hydrocarbons.

invar. An alloy of Fe and Ni (36%) which has a very low coefficient of thermal expansion. Used in the manufacture

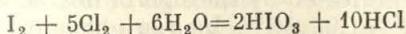
of accurate instruments which should not be affected by temperature changes.

inversion of sucrose. The hydrolytic conversion of sucrose into a mixture of glucose and fructose.

iodates. Salts of iodic acid, HIO_3 , stable, strong oxidizing agents. Iodates react with iodides in the presence of an acid to yield iodine:



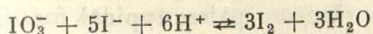
iodic acid HIO_3 . A crystalline substance stable at room temperature. Obtained in aqueous solutions by the oxidation of iodine with chlorine or concentrated nitric acid:



Salts of iodic acid are called iodates.

iodides. Salts of hydriodic acid, HI ; very soluble in water, except for AgI , Cu_2I_2 , and Hg_2I_2 ; some iodides are soluble in polar organic solvents such as alcohols, ketones, and esters. Sodium and potassium iodides are used in medicine, in the organic synthesis, in the analytical chemistry.

iodimetry (iodometry). A volumetric analytical technique based on redox reactions involving iodine or iodide anion ($\text{I}_2 + 2\bar{e} \rightleftharpoons 2\text{I}^-$). The technique can be used to determine acids:



iodine [Gk *iodēs*, violetlike] I. A Group VII element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 53, atomic mass 126.9044; one stable isotope, ^{127}I ; belongs to the halogen family. Discovered in 1811 by Courtois.

Properties: greyish-black crystals having a violet metallic lustre. Readily sublimed at room temperature to form violet vapour of pungent odour. Soluble in most organic solvents. The oxidation states in compounds —1 (iodides), +5 (iodates), and +7 (periodates); less reactive than chlorine and bromine, directly combines with hydrogen, some metals and non-metals; iodine is easy to isolate in the free state by the action of oxidants on iodides in aqueous solutions; strong oxidants convert iodides to iodates.

Occurrence: naturally occurring iodine compounds are sodium, potassium, and magnesium iodides; some seaweeds extract iodine from sea water.

Derivation: from seaweeds and oil-well brines.

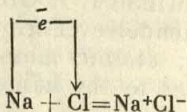
Uses: medicine, laboratory work; in industry, iodine is used for refining metals. Radioactive iodine isotopes are employed in biology, medicine, and chemistry. Lack of iodine is the cause of goiter.

iodoform CHI_3 . Yellow crystals with a strong characteristic odour. Used in medicine as antiseptic.

ion [Gk *ienai*, to go]. A particle consisting of an atom or a group of atoms bearing a positive or negative charge. Anions are indicated by the sign minus, and cations plus, as Na^+ , Zn^{2+} , Cl^- , SO_4^{2-} . Ions are chemically active and react with atoms, molecules, and each other. Ions are formed in solutions as a result of the electrolytic dissociation. Their presence determines the properties of electrolytes.

ion exchanger. An insoluble solid which can exchange its ions for those present in solution, usually a synthetic resin containing basic or acidic groups. Ion exchangers may be cation or anion exchangers. Uses: water desalting, separation of substances (see *chromatography*), other technological uses.

ionic bond (electrovalent bond). A bond formed by the transfer of electrons from one atom to another and the formation of electron pairs; typical for linkages between metals and most active non-metals, e.g.



ionic exchange. Exchange of ions between two electrolytes, can go both in homogeneous media (in true solutions of several electrolytes) and in heterogeneous systems where one of the electrolytes involved is in the solid state (between solutions and precipitates, ion exchangers, etc.).

ionic radius. The radius of an ion calculated on the assumption that ions are rigid spheres whose dimensions are independent of the composition of molecules containing them; used to predict atomic spacings in ionic compounds.

ionic strength of solutions. A measure of the strength of the electric field generated by ions in solutions.

ionization. The formation of ions from neutral atoms or molecules, an endothermic process.

ionization potential. The smallest energy needed to remove an electron from an atom, ion, molecule, or radical. It is usually calculated for the ground states of the initial and ionized particles.

iridium [Gk *iris*, rainbow] Ir. A Group VIII element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 77, atomic mass 192.2, belongs to the platinum family. Discovered by Tennant in 1804.

Properties: silvery white metal, very hard and brittle. Insoluble in acids and *aqua regia*, stable to chemical actions; the oxidation states are usually +3, +4; forms various complex compounds such as $(\text{NH}_4)_2[\text{IrCl}_6]$. Iridium derives its name from the colours of its salts which may be green, red, and violet.

Occurrence: rarely found in the free state, more frequently as iridosmine etc.

Uses: as a catalyst in the organic synthesis; alloys with platinum are used for electric contacts, thermocouples, for tipping various instruments, in watchmaking, in the manufacture of physical, chemical, medical (surgical) equipment, etc.

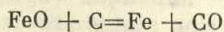
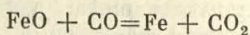
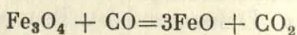
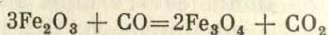
iron [Anglo-Saxon name, L *ferrum*, iron] Fe. A Group VIII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 26, atomic weight 55.847. Known from the earliest times: iron tools and weapons have been used from 800-600 B.C. (the Iron Age); the introduction and development of metallurgy dates from the same period.

Properties: a silvery white ductile metal, very malleable. Moderately active, the oxidation states in compounds +2, +3; heating of iron in the air results in the formation of a protective oxide film; in moist air undergoes oxidation and turns covered by rust. Iron easily dissolves in dilute acids, but concentrated acids make it passive (chemically unreactive). Iron reacts with most elements.

Occurrence: one of the most abundant elements, occurs in the free state and in ores.

Derivation: by the reduction of iron carbonate (siderite) or iron(III) oxide (hematite) with carbon monoxide.

In industry, iron is produced in the form of various alloys with carbon (pig iron, steel). Pig iron is obtained in blast furnaces, steel by the open-hearth (Siemens-Martin) and Bessemer processes, or by electrosmelting. In blast furnaces ores are smelted with coke and limestone; carbon contained in coke is oxidized by air oxygen, $C + O_2 = CO_2$. Carbon dioxide interacts with coke to give CO, $C + CO_2 = 2CO$, which, together with coke, gradually reduces iron oxides:



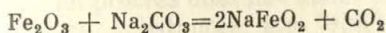
Uses: mostly iron alloys are used, e.g. high-carbon and alloyed steels, special grades of pig iron. Technically pure iron is employed in the manufacture of cores of electromagnets and armatures of electrical devices. The most widely applied iron compounds are its oxides, FeO, Fe_3O_4 , and Fe_2O_3 ; iron nitrate, $Fe(NO_3)_3 \cdot 6H_2O$; iron sulphates, $FeSO_4 \cdot 7H_2O$ and $Fe_2(SO_4)_3 \cdot 9H_2O$; chlorides, $FeCl_2 \cdot 6H_2O$ and $FeCl_3 \cdot 6H_2O$; ammonium ferric alum, $NH_4Fe(SO_4)_2 \cdot 12H_2O$. Iron forms various complex compounds such as $K_4[Fe(CN)_6]$ and $K_3[Fe(CN)_6]$. Iron is contained in hemoglobin and plays an important part in biological processes.

iron blues. See *Berlin blue*.

iron ores. The most important are: limonite (brown hematite, brown iron ore), $2Fe_2O_3 \cdot 3H_2O$, contains 55 to 30% or less iron; hematite (red hematite, red iron ore, Fe_2O_3 ; magnetite (iron ore, magnetic), Fe_3O_4 ; siderite (spatic iron ore), $FeCO_3$.

iron oxides and hydroxides. Ferrous oxide, FeO, occurs as black crystals, practically insoluble in water, readily soluble in acids, liable to oxidation. Obtained by hydrogen reduction. Ferrosoferric oxide (magnetic iron oxide), Fe_3O_4 , black crystals, dissolves in acids to give mixtures of Fe(II) and Fe(III) salts, undergoes oxidation to Fe_2O_3 upon heating in the air, occurs in nature as magnetite, an important iron ore. Ferric oxide, Fe_2O_3 , dark-red to black-violet crystals, soluble in acids.

Natural ferric oxide, hematite, is an important iron ore, also used as brown paint pigment (colcothar). Ferrous hydroxide, $\text{Fe}(\text{OH})_2$, is made by the action of alkalis on $\text{Fe}(\text{II})$ salts, easily undergoes oxidation to $\text{Fe}(\text{OH})_3$. Ferric oxide, $\text{Fe}(\text{OH})_3$, is a red-brown substance, readily dissolves in acids. It loses water upon calcination to give ferric oxide, Fe_2O_3 . Ferric hydroxide shows weak acidic properties. Fusing Fe_2O_3 together with Na_2CO_3 or K_2CO_3 results in the formation of metal ferrites (cf. *metal aluminates*):

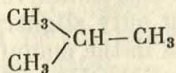


iron vitriol (ferrous sulphate) $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$. Greenish crystals, used in the textile industry, in agriculture (as insecticide), in the manufacture of mineral paints. Forms double salts with alkali metal and ammonium sulphates, e.g. $(\text{NH}_4)_2 \cdot \text{SO}_4 \cdot \text{FeSO}_4 \cdot 6\text{H}_2\text{O}$ known as Mohr's salt and used in the analytical chemistry.

isobar [iso + Gk *baros*, weight]. Any of two or more atoms having the same weight but different nuclear charges (atomic numbers) and chemical properties. Isobars represent different chemical elements, e.g. ^{40}Ar , ^{40}K , and ^{40}Ca ; ^{54}Cr and ^{54}Fe ; ^{112}Cd and ^{112}Sn , etc.

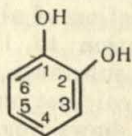
isobutylene $(\text{CH}_3)_2\text{C}=\text{CH}_2$. An unsaturated hydrocarbon, contained in gases resulting from cracking of petroleum, used for the preparation of isooctane, synthetic rubber, and synthetic resins.

isomer. Any of two or more chemical compounds having the same composition and molecular mass but different molecular structures, physical and chemical properties. For example, *n*-butane, $\text{CH}_3-(\text{CH}_2)_2-\text{CH}_3$, has a b.p. of $+0.6^\circ\text{C}$ while isobutane



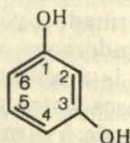
boils at -11.7°C . The three possible isomeric forms of disubstituted benzenes are called *ortho*-, *meta*-, and *para*-isomers and are usually denoted by the letters *o*-, *m*-, and *p*- before the name of the compound. The substituents are in the positions 1,2 (at adjacent carbon atoms) in *ortho*-isomers, 1,3 in *meta*-isomers, and 1,4 in

para-substituted benzenes, e.g.



pyrocatechol

ortho-dihydroxybenzene



resorcinol

meta-dihydroxybenzene



hydroquinone

para-dihydroxybenzene

See also *stereoisomerism*.

isometry [iso + Gk *metron*, measure]. Equality of qualitative and quantitative compositions of substances differing in their properties. The phenomenon is explained by different molecular structures of such substances. It is one of the reasons for organic compounds being so numerous. See *isomer*.

isomorphism [iso + Gk *morphe*, form]. The ability of atoms, ions, or molecules to replace each other in crystals with the formation of mixed crystals of variable compositions called substitutional solid solutions. Examples are KCl and KBr, BaSO₄ and RaSO₄, KH₂PO₄ and KH₂AsO₄.

isooctane. See *octane*.

isoprene CH₂=C(CH₃)-CH=CH₂. An unsaturated hydrocarbon of the C_nH_{2n-2} series, a colourless liquid soluble in ethanol. Easily polymerizes in the synthesis of rubber. Also polymerizes with compounds of the vinyl series. Used in the manufacture of synthetic rubber.

isoprene rubber. A synthetic rubber made by the polymerization of isoprene in the presence of lithium metal or peroxides as catalysts. Has adhesiveness similar to that of natural rubber being only slightly inferior to the latter in its elasticity. Used in the manufacture of rubber goods.

isopropyl alcohol CH₃-CH(OH)-CH₃. A colourless liquid with a characteristic odour, a good solvent for many essential oils, synthetic resins, and alkaloids. Used as antifreeze.

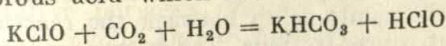
isopropyl ether (CH₃)₂CH-O-CH(CH₃)₂. A colourless mobile liquid with a characteristic ether odour, used to dissolve oils, fats, carboxylic acids, etc., and also as an admixture to gasoline increasing its octane number.

isotope [iso + Gk *topos*, place]. Any of two or more forms of an element whose nuclei contain the same number of protons but different numbers of neutrons. Isotopes have the same number of electrons and occupy the same position in the Mendeleev Periodic Table of Elements. Stable isotopes remain unchanged indefinitely, and unstable (radioactive) isotopes undergo spontaneous disintegration. Isotopes are used in various scientific and technological areas. See *tracer*.

isotope exchange. A redistribution of isotopes between reacting substances. The process does not affect the elementary compositions of the substances, e.g. $^{14}\text{NH}_4^+ + ^{15}\text{NH}_3 = ^{15}\text{NH}_4^+ + ^{14}\text{NH}_3$. Such reactions can also involve different isotopic forms of the same substance, e.g. $\text{H}_2\text{O} + \text{D}_2\text{O} = 2\text{HDO}$.

J

Javelle water [Fr *eau de Javelle*, from the place where it was originally produced]. A solution of salts of hydrochloric and hypochlorous acids ($\text{KClO} + \text{KCl}$). Used for bleaching. Potassium hypochlorite readily decomposes under the action of atmospheric CO_2 with the formation of hypochlorous acid which has a decolourizing action:



K

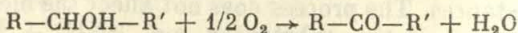
kainite [Gk *kainos*, new]. A mineral, a double salt of magnesium and potassium, $\text{KCl} \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$. Colour grey, yellow, or red. Used in the manufacture of potassium fertilizers, magnesium metal.

kaolin (China clay, porcelain clay). A loose rock, a product of weathering of feldspars, mica, and granite; its major component is kaolinite, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$, also contains various admixtures such as quartz, feldspar, etc. Used in the manufacture of refractories, porcelain, faience, and also in the paper, rubber, silicate, cable industries, perfumery, etc.

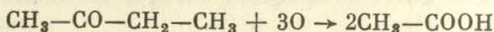
Kapron. Nylon-like synthetic fibre.

kerosine (kerosene). A mixture of hydrocarbons obtained by the distillation of petroleum with a boiling range from 180 to 230 °C; a transparent, colourless or yellowish liquid, used as a jet fuel, a fuel for carburetor tractor engines, and a fuel for household needs. Also used as herbicide in agriculture.

ketone. A compound containing the carbonyl group, $>\text{C}=\text{O}$, in between two hydrocarbon radicals. Prepared by the oxidation of secondary alcohols:



The lower ketones are liquids soluble in water, the higher ones are insoluble solids. All ketones are soluble in organic solvents. Ketones are less reactive than aldehydes, can only be oxidized by strong oxidizing agents which break ketone molecules to yield two carboxylic acids:



They do not give the reaction of silver mirror, but are capable of addition reactions. The reduction of ketones yields secondary alcohols. Ketones, e.g. acetone, are effective solvents widely employed in industry; they are also important intermediate products for the organic synthesis.

kinetic methods of analysis. The methods of chemical analysis utilizing the relationship between the reaction rate and the reagent concentrations. The substance that has to be determined may participate in the reaction or be a catalyst. Kinetic methods are characterized by high sensitivity; they are used to determine trace elements, negligibly small concentrations of various admixtures in metals and their alloys, in water, in high purity reagents.

kinetics [Gk *kinein*, to move]. A study of chemical reaction rates. The term 'reaction kinetics' is understood to imply the dependence of the reaction rate on the reagent concentrations, temperature, and other factors (such as the electrode potential in electrochemical reactions, the irradiation dose in radiochemical reactions, etc.).

krypton [Gk *kryptein*, to hide] Kr. A Group VIII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 36, atomic mass 83.80, an inert gas. Isolated from the air in 1898 by Ramsay and

Travers. Krypton compounds with fluorine (KrF_4), phenol, chloroform, etc. have been obtained. In industry is obtained from the air; used for filling incandescent lamps, electric luminescent tubes (gives white glow) The ^{85}Kr isotope is used as tracer.

Kuchеров's reaction. See *acetylene*.

kurchatovium (after Russian physicist Kurchatov) Ku. A Group IV radioactive element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 104. Synthesized in 1964 by Flerov and co-workers (Dubna, USSR); chemically identified in 1966. Has isotopes with the mass numbers 257, 259, 260, and 261. Resembles hafnium in its chemical properties.

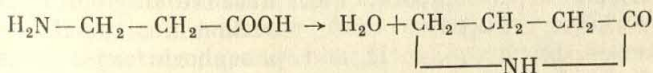
L

lachrymator [L *lacrima*, a tear], also spelled lacrimator.

A tear gas, a substance producing an irritating effect on the eyes, e.g. chloroacetone, bromobenzyl cyanide, chloropicrin, etc.

lacquer. A colloidal solution of synthetic or natural resins in organic solvents. Used to produce films protecting materials from external influences such as corrosion and for decorative purposes (lacquer-dye coatings).

lactam. Any of cyclic amides produced from amino acids by the removal of one molecule of water, e.g.



Depending on the type of the starting acid, beta-, gamma-, delta-, and epsilon-lactams may be formed. An example is epsilon-caprolactam used in the manufacture of synthetic fibres.

lactic acid (2-hydroxypropanoic acid*, alpha-hydroxypropionic acid, milk acid) $\text{CH}_3-\text{CH}(\text{OH})\text{COOH}$. A substance widely distributed in nature, found in sour cabbage, pickled food, sour milk; formed in lactic fermentation of sacchariferous compounds. Contained in muscles, being the product of splitting of glycogen (animal starch): during muscle activity, the amount of lactic acid in muscles in-

creases which is one of the factors causing bodily fatigue. During rest, lactic acid is partly converted to glycogen and partly oxidized to CO_2 and H_2O . Used in the manufacture of leather, dyeing, medicine.

lactose (milk sugar) $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A disaccharide contained in milk, incorporates the glucose and galactose residues. Dilute acids hydrolyse lactose under reflux. Obtained from whey, used to prepare nutrient media, e.g. in the production of penicillin.

lanthanides, lanthanons. The 4f family of 14 elements with atomic numbers from 58 to 71 of the 6th period of the Mendeleev Periodic Table of Elements; follow immediately after lanthanum (atomic number 57). Lanthanides are subdivided into two groups, the cerium group including La, Ce, Pr, Nd, Pm, Sm, Eu, and the yttrium group including Gd, Tb, Dy, Ho, Er, Tu, Yb, Lu. In nature lanthanides accompany each other; the isolation of pure elements is an exceedingly difficult task because of the close similarity of their chemical properties. "Yttrium earths" were discovered as early as 1794 by Gadolin in a mineral found in Sweden and called gadolinite afterwards. In 1803, Klaproth and Berzelius independently discovered a new "cerium earth". During the years that followed all the lanthanides were discovered and isolated from either yttrium or cerium earths. All of them are silvery white metals, ductile and malleable. Lanthanides are reactive and form stable oxides, halides, sulphides, react with hydrogen, carbon, nitrogen, phosphorus, decompose water, dissolve in hydrochloric, sulphuric, and nitric acids. Lanthanides remain unattacked by hydrofluoric and phosphoric acids because of the formation of protective films of poorly soluble salts. Form complex compounds with a number of organic compounds; of these, complexes with citric and ethylenediaminetetraacetic acids are of importance for the separation of lanthanides. In industry lanthanides are prepared by reducing their halides with pure calcium or by electrolysis of melts. Lanthanides are used as alloying admixtures to steel, pig iron and other alloys to improve their mechanic properties, resistance to corrosion and heating. Lanthanides are also used as components of special kinds of glass, in nuclear technology. Lanthanide compounds

are employed in the manufacture of lacquers and pigments, phosphors, leather, in the textile industry, in electronic devices as materials for cathodes. Lanthanide compounds are used in lasers.

lanthanons. Same as *lanthanides*.

lanthanum [Gk *lanthano*, to lie hidden] La. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 57, atomic mass 138.91. Discovered by Mosander in 1839 in the form of lanthanum oxide.

Properties: a ductile and malleable metal. Decomposes water at room temperature, readily dissolves in dilute acids; the oxidation state in compounds +3.

Occurrence: found in monazite, a mineral of a complex composition.

See *lanthanides*.

lapis lazuli (lazulite). A silicate mineral, brittle, colour deep blue to greenish blue. Dissolves in HCl with evolution of H_2S . Used as a rare beautiful ornamental stone, a material for vases, caskets, statuettes. Thin plates are used in mosaic, for facing columns, mantels, etc.

latex [L *latex*, a fluid, liquid]. A water emulsion of rubber-like polymers, can be natural or synthetic. Natural latex is a milky sap from the rubber tree. Used in the manufacture of rubber, rubber goods, to make foam and sponge rubber, in the production of synthetic leather and rubber cloth. Synthetic latex is a water emulsion of rubber-like polymers obtained by polymerizing or co-polymerizing various organic unsaturated compounds. Synthetic latex is used in the manufacture of various rubber goods, dyes, in impregnating paper, to insulate wires, as an adhesive.

Lavoisier-Laplace law. The decomposition of a complex compound into simple ones is accompanied by release (absorption) of as much heat as is absorbed (released) in the formation of the same compound from simple substances.

law of constant composition (Proust, 1801-1808). A definite chemical compound always contains the same elements chemically combined in the same proportions by weight, irrespective of the method of its synthesis. One of the principal laws of chemistry. Does not hold with a large group of compounds of variable composition (bertholliides).

law of multiple proportions. If two elements form more than one compound the weights of one of the elements which combine with a given weight of the other element are related to each other as integer numbers. For example, the weights of carbon which combine with the same amount of hydrogen to form methane and ethylene are in the ratio of 1:2. The law was formulated by Dalton in 1803.

lawrencium (after E.O. Lawrence, American physicist, the inventor of cyclotron) Lr. A radioactive element of the actinide family, atomic number 103. Synthesized in the USA in 1961 as ^{257}Lr ; the oxidation state +3.

lead [prob. Celt. word] Pb. A Group IV element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 82, atomic mass 207.19. Long known.

Properties: a soft, ductile, malleable metal of grey colour. When exposed to air lead is covered by a protective oxide film preventing further oxidation; stands immediately before hydrogen in the electromotive series. Dilute hydrochloric and sulphuric acids exhibit practically no action on the metal because of the low solubilities of PbCl_2 and PbSO_4 films; dissolves in nitric acid. Like its hydroxide lead dissolves in alkalis with the formation of plumbate anions, $\text{Pb}(\text{OH})_4^{2-}$. All soluble lead compounds are poisonous. The oxidation states are +2, +4; tetravalent lead compounds are far less stable than their divalent counterparts.

Occurrence: in the free state found only rarely; the most important mineral is galena (lead glance), PbS .

Derivation: by roasting lead glance to lead oxide followed by reducing the product with carbon to obtain lead metal.

Uses: cable covering, storage batteries, a constituent of babbitt metal, type metal, etc. Absorbs gamma-rays strongly and therefore used as a shield in handling radioactive materials. See *lead oxides*, *lead white*, *tetraethyllead*.

lead oxides. Lead forms two simple oxides, PbO and PbO_2 , and two mixed oxides, Pb_2O_3 and Pb_3O_4 , where lead occurs in both its oxidation states simultaneously. Yellow powder of lead(II) oxide, litharge, is used to fill cells of storage battery plates, in the manufacture of some sorts of lead glass. Minium, Pb_3O_4 , is a bright red

powder used as pigment in oil paint for protecting iron and steel structures, e.g. hulls, from corrosion. Lead dioxide, PbO_2 , is an oxidizing agent; it is also used in storage batteries.

lead white. Basic lead carbonate, $2\text{PbCO}_3 \cdot \text{Pb(OH)}_2$, soluble in acids and alkalis, stable to the action of light and moisture. Used for painting ships, etc. Hydrogen sulphide turns the substance dark because of the formation of black lead sulphide which is the reason why oil-paint pictures darken with time. The initial colours may be restored with the help of dilute hydrogen peroxide which transforms lead sulphide to white lead sulphate. Has only limited applicability because of its toxicity.

Le Chatelier principle (1884): If a system in equilibrium is subjected to a stress which affects temperature, pressure, or concentration conditions, the system tends to react in such a way as to oppose the effect of the stress. Increase of temperature shifts the equilibrium on the side of the process accompanied by absorption of heat. Increase of pressure favours the process resulting in decrease of volume. The introduction of an additional amount of one of the reagents shifts the equilibrium in the direction such that the compound added be consumed.

lecithin. An ester of the amino alcohol, choline, and a diglyceride phosphoric acid. Lecithins are the most important phosphatides; their molecules contain residues of fatty acids (stearic, palmitic, oleic, etc. acids). Found in all animal and vegetable tissues. Large amounts of lecithins occur in egg yolk and erythrocytes. In organisms, lecithins participate in metabolism of fatty acids. Used in medicine against anaemia, in the food industry (margarine production), in cosmetics, in the manufacture of leather, in the textile industry.

lewisite (dichloro(2-chlorovinyl)arsine) (after W. Lewis, American chemist). A dark-brown liquid with a sharp irritating odour, a mixture of various isomers of the title compound. $\text{ClCH}=\text{CHAsCl}_2$, a blistering poison gas.

ligand [L *ligare*, to bind, tie] (addend). A molecule or an ion linked with the central ion of a complex compound.

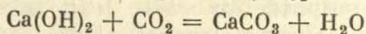
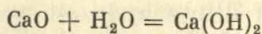
lignin [L *lignum*, wood]. A complex organic substance of the aromatic series, insoluble in water, saturating wood cell membranes. Wood contains about 30% lignin.

lignite. Solid fossil coal formed from peat, contains 60 to 70% carbon, brown in colour, the newest of fossil coals, used as fuel and as raw material in the chemical industry.

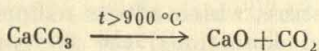
ligroin. A mixture of liquid hydrocarbons obtained by distilling or cracking petroleum; a transparent yellowish liquid. Used as diesel fuel, as solvent in the manufacture of dyes and lacquers, as hydraulic liquid in some devices.

lime (calcium oxide, quicklime) CaO .

Properties: a white substance, effectively absorbs moisture and carbon dioxide:



Derivation: by roasting limestone or chalk:



Uses: making cement, glass, calcium carbide, slaked lime.

lime, slaked, calcium hydroxide, Ca(OH)_2 . Obtained by the action of water on quicklime. A strong base with a relatively low solubility in water. Used in building, in the chemical industry, in the production of sugar, etc.

limestone. A sedimentary rock composed mainly of calcite, CaCO_3 . Used in building, cement production, in metallurgy, in the manufacture of soda, chlorinated lime, calcium carbide, mineral dyes, and in agriculture for liming soil.

lime water. A saturated aqueous solution of calcium hydroxide, Ca(OH)_2 , alkaline, turns turbid in the air because of the absorption of carbon dioxide and formation of CaCO_3 . Used for the detection of CO_2 and in medicine.

limiting current. An electric current density that corresponds to the limiting value of the rate of the slowest process involved in an electrolytic reaction. For example, the diffusion of the reactants to electrodes may be the rate determining step if the reactant concentrations near the electrodes decrease to zero; the limiting diffusion current is then attained.

lipase [Gk *lipos*, fat]. An enzyme which catalyzes the hydrolytic splitting of fats into glycerol and fatty acids. Used in the manufacture of some vitamins, e.g. vitamin A, fatty acids, leather, cheese, in medicine.

lipid [Gk *lipos*, fat]. A term used to define fats and fat-like materials. Lipids are insoluble in water, very soluble in alcohols, ether, chloroform, and benzene. Include fats, waxes, and a group of lipoids: phosphatides (phospholipids), sterols (e.g. cholesterol), and steroids. Lipids are important biological substances contained in all living cells from which they can be isolated by extracting them with organic solvents. Individual lipids are separated chromatographically. Used as food, in medicine, and in various industries.

lipoproteins. Complex substances incorporating proteins and lipids, contained in all animal cells and tissue, mostly in nerve tissue. Also found in plant tissue.

liquid fertilizers. Nitrogenous and complex fertilizers used in the liquid state such as liquid ammonia, ammonia water, ammonia complexes, and complex fertilizers containing nitrogen, phosphorus, potassium, and microelements.

lithium [Gk *lithos*, a stone] Li. A Group I element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 3, atomic mass 6.939, discovered by Arfvedson in 1817.

Properties: silvery white colour, the lightest metal. Belongs to alkali metals, the oxidation state in compounds +1, turns tarnished in the air because of the formation of the oxide, Li_2O , and nitride, Li_3N ; reacts with water less vigorously than the other alkali metals; lithium hydroxide is a strong base. Lithium and its compounds give carmine-red coloration when put into flame.

Occurrence: rather wide-spread, occurs in rocks, mineral springs, sea water, bituminous coal, soil, animal and plant tissues.

Derivation: by the electrolysis of lithium chloride.

Uses: an important element for nuclear energy devices, the ${}^6_3\text{Li}$ isotope is employed in the preparation of tritium: ${}^6_3\text{Li} + {}^1_0\text{n} = {}^3_1\text{H} + {}^4_2\text{He}$; lithium is used as material for control rods in uranium piles and as coolant, in ferrous and nonferrous metallurgy, in chemistry (organolithium compounds). Lithium compounds are used in the manufacture of glass etc.

lithopone. A mixture of barium sulphate and zinc sulphide, BaSO_4 and ZnS , used as white pigment.

lithosphere. See *earth's crust*.

litmus. A dye obtained from some lichens, changes colour with acidity of solution, red in acid and blue in basic media. Used as indicator.

luminal. See *phenobarbital*.

luminescence [L *lumen*, a light]. Emission of electromagnetic radiation from a substance as a result of any non-thermal process. Luminescence may be caused by radiation from radioactive substances, cathode rays, X-rays, etc. If luminescence ceases as soon as the source of energy is removed the phenomenon is called fluorescence, otherwise it is phosphorescence. Widely applied in the analytical chemistry to detect and determine various substances.

luminophore. See *phosphor*.

lutecium, lutetium [L *Lutetia*, city in Gaul, now Paris] Lu. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 71, atomic mass 174.97, belongs to the lanthanide family. The oxidation state in compounds +3.

lyophilic and lyophobic substances. See *hydrophilic and hydrophobic substances*.

M

macromolecule. A combination of a large number of atoms linked by chemical bonds. Substances built of macromolecules are known as high-molecular-weight compounds. The number of atoms in a macromolecule may be very large, of hundred thousands or millions.

macronutrient. An element needed for plants in large amounts (cf. *micronutrient*), e.g. nitrogen, phosphorus, sulphur, potassium, magnesium, and calcium. Carbon, oxygen, and hydrogen may also be regarded as macroelements.

magnesia. An old name for magnesium oxide, MgO (also called burnt magnesia etc.), used in medicine as antacid.

magnesite. A natural magnesium carbonate, $MgCO_3$, colour may be white, yellowish, grey; brittle. Used mainly in the manufacture of refractories and cements, in the chemical industry.

magnesium [Gk *Magnesia lithos*, stone of Magnesia, district in Thessaly] Mg. A Group II element of the 3rd period of

the Mendeleev Periodic Table of Elements, atomic number 12, atomic mass 24.305. First isolated by Davy in 1808 as magnesium amalgam, prepared in coherent form by Bussy in 1828.

Properties: a light silvery white metal, turns tarnished in the air because of oxidation. The oxidation state in compounds +2; very reactive, burns with an intense white light in the air, reacts vigorously with some other elements, slowly replaces hydrogen from water under reflux; does not react with alkalis. Magnesium is a strong reducing agent, at high temperatures reduces metals from their oxides and halides, e.g. alkali metals, beryllium, aluminium, etc.; also reduces nonmetals such as boron and silicon.

Occurrence: various silicate rocks (serpentine, olivine, etc.), magnesite, dolomite, carnallite, etc.; also found in sea water, mineral springs, etc.

Derivation: by the electrolysis of MgCl_2 (carnallite).

Uses: magnesium metal is mostly used in the production of light alloys, e.g. with aluminium (10% Mg + 90% Al); it is also employed to isolate Ti, Zr, V, U, and other metals, in the manufacture of pig iron to increase its strength, in flash bulbs, incendiary bombs, etc. The most important magnesium compounds are magnesium oxide, MgO (magnesia), used in the manufacture of high-temperature crucibles and refractory bricks, in medicine; magnesium sulphate (Epsom salts), $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, contained in sea water, used as a laxative; magnesium carbonate (magnesite), MgCO_3 , used in building and in the chemical industry. Magnesium forms many organic derivatives used in various organic syntheses, e.g. Grignard reagents RMgX , where X is a halogen. A mixture of MgO , MgCl_2 , and H_2O gives $\text{Mg}(\text{OH})\text{Cl}$ upon solidification and can be used as a binder. Magnesite and dolomite, $\text{MgCO}_3 \cdot \text{CaCO}_3$, are used in the manufacture of refractories and as fertilizers: magnesium salts are essential to plants because chlorophyll contains magnesium.

magnesium perchlorate, anhydrous, $\text{Mg}(\text{ClO}_4)_2$. A white porous solid, very strongly absorbs water (in amounts up to 60% of its dry weight) to give the hydrated salt; unlike P_2O_5 it is not deliquescent and is therefore more convenient to use for drying gases.

magnetite (iron ore, magnetic) $\text{FeO} \cdot \text{Fe}_2\text{O}_3$. A black mineral, strongly magnetic. An important iron ore, contains 72.4% Fe.

magnetochemistry. A branch of physical chemistry that studies relations between the magnetic and the structural characteristics of substances.

malachite. A carbonate mineral, anhydrous basic copper carbonate, $\text{Cu}_2(\text{OH})_2\text{CO}_3$. Brittle. Colour bright-emerald to grass-green, sometimes nearly black. Lustre adamantine, dull, or silky (fibrous varieties). Easily dissolves in dilute acids. Used as material for ornamental stoneware and as copper ore.

malathion. A contact insecticide and acaricide, one of the least poisonous to man and animals pesticides.

malic acid (hydroxybutanedioic acid*, hydroxysuccinic acid, apple acid) $\text{HOOC}-\text{CH}(\text{OH})-\text{CH}_2-\text{COOH}$. A dibasic hydroxycarboxylic acid, found in unripe apples, grapes, mountain-ash berries, etc. An intermediate formed in respiration in animals and plants. Used in the food industry and medicine.

malonic acid (propanedioic acid*, methanedicarboxylic acid) $\text{HOOC}-\text{CH}_2-\text{COOH}$. A dibasic acid of the saturated series. Malonic acid and its derivatives are used in the manufacture of vitamins B_1 and B_2 , amino acids, and other organic compounds.

maltase (glucose). An enzyme catalyzing the hydrolysis of maltose to two glucose molecules. Occurs in saliva, intestine, blood, liver, and in large amounts in yeast.

maltose (malt sugar) $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A disaccharide, composed of two glucose residues, very common in plants. Maltose is formed in animals as an intermediate product of the dissociation and synthesis of starch and glycogen. Shows reducing properties. The action of dilute acids under reflux and of maltase results in the hydrolysis of maltose with the formation of two glucose molecules, $\text{C}_6\text{H}_{12}\text{O}_6$. Maltose is easily assimilated in man.

manganate. A salt of unstable manganic acid, H_2MnO_4 .

manganese [by metathesis from magnesia, see *magnesium*] Mn. A Group VII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 25, atomic mass 54.938, one stable isotope. Discovered by Gahn in 1774.

Properties: a white silvery brittle metal. Gets oxide film coating in the air, soluble in acids; the oxidation states in compounds +2, +3, +4, +6, +7.

Occurrence: the most important ores are pyrolusite, $\text{MnO} \cdot n\text{H}_2\text{O}$ (earlier called black magnesia whence the name of the element); braunite, $\text{Mn}_2\text{O}_3 \cdot n\text{SiO}_2$.

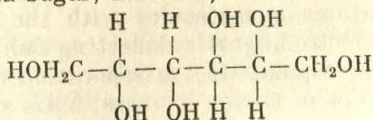
Derivation: by the electrolysis of solutions of MnSO_4 or reduction of manganese oxide with silicon in electric furnaces.

Uses: a constituent of all kinds of steel and pig iron; ferromanganese is an alloy containing 70 to 80% manganese which is employed as a deoxidizer and alloying element in the manufacture of steel; included in some nonferrous alloys, e.g. bronzes, Manganin, etc. Manganese is a nutrient element essential to plants and animals. See *manganese compounds*.

manganese compounds. The most important are Mn^{2+} salts, manganese dioxide, MnO_2 , and potassium permanganate. Manganous oxide, MnO , is a basic oxide, dissolves in acids to give Mn^{2+} salts, e.g. MnSO_4 which is a micro-fertilizer. MnO is a semiconductor, it is also used in the manufacture of ferrites and paints. $\text{Mn}(\text{OH})_2$ is a weak base formed as a white precipitate which turns brown in the air because of oxidation to $\text{Mn}(\text{OH})_4$. Manganese dioxide, MnO_2 , is an oxidizing agent, used in dry batteries as catalyst. Manganese(VI) derivatives include salts of unstable manganic acid, manganates, e.g. potassium manganate K_2MnO_4 ; these salts are dark-green substances. Salts of permanganic acid, HMnO_4 , called permanganates are of greater importance. An example is potassium permanganate, KMnO_4 , a violet solid, a powerful oxidizing agent. Cyclopentadienyltricarbonylmanganese is the organomanganese derivative used as an anti-knock agent less toxic than tetraethyllead.

manganin. Tradename for an alloy of copper (84%), manganese (12%), and nickel (4%), used in the manufacture of wire whose resistance is almost independent of temperature.

mannitol (manna sugar, mannite)



A hexahydric alcohol, contained in many plants. Mannitol and its derivatives are used in the manufacture of surfactants, drying oils, resins, lacquers, and also in the food industry and perfumery.

marble. Various carbonate rocks mainly containing calcite, CaCO_3 , or dolomite, $\text{CaMg}(\text{CO}_3)_2$. Colour white, grey, red, etc. Used in building and in electrical devices.

marsh gas. Natural methane with small admixtures of N_2 and CO_2 , formed in the decomposition of plant residues in the absence of oxygen under the action of bacteria, under standing water.

masking in the analytical chemistry. Binding of ions that interfere with the detection, determination, or separation of certain components into almost undissociated complexes; e.g. iron(III) interferes with the determination of nickel(II) in the form of nickel dimethylglyoximate because it forms a $\text{Fe}(\text{OH})_3$ precipitate under the reaction conditions; however in the presence of tartaric acid, iron will remain in solution as an almost undissociated soluble coordination compound. The most familiar reagents used for masking are carboxylic acids such as citric, tartaric, acetic, oxalic, chelating agents, and some inorganic ions (F^- , CN^- , etc.).

mass action law. Relates the concentrations of reagents which are in equilibrium with each other, formulated by Guildberg and Waage in 1864-1867. According to that law the velocity of a chemical change is proportional to the active masses (concentrations) of the reacting substances. The law is used in various chemical calculations, e.g. to predict the reaction direction at given reactant concentrations, the yield that can be obtained, etc.

mass number. The number of nucleons, i.e. the summed number of protons and neutrons, in an atomic nucleus. Symbol: A. It is written as superscript on the left-hand side of the element symbol, as ^{238}U for the uranium isotope with the mass number 238.

mass spectrometry. A method for studying substances by measuring masses of atoms and molecules it incorporates. A mass spectrometer separates streams of charged rays of ionized atoms or molecules with the help of electrostatic and electromagnetic deflecting fields. The resulting spectrum corresponds to the separation of particles with different ratios of charge to mass. Mass spectrum may be

used to determine component masses and percentages in a substance. The technique is employed for the determination of accurate atomic masses, the analysis of the isotope and chemical compositions of substances, the determination of the structure of molecules, etc.

matte. An intermediate product in the manufacture of some nonferrous metals (Cu, Ni, Pb, etc.) from their sulphide ores, an alloy of ferrous sulphide, FeS, with a nonferrous metal sulphide, e.g. Cu_2S .

mendelevium (after D. I. Mendeleev) Md. A radioactive element of the actinide family, atomic number 101, synthesized in the USA in 1955. The longest lived isotope, ^{258}Md , has a half-life of 54 days; the other isotope, ^{256}Md , decays with $T_{1/2} = 30$ min. The oxidation states +2, +3.

menthol. A constituent of peppermint oil from which is obtained by freezing; a crystalline solid with a characteristic odour. Used in medicine to relieve headache, as an antiseptic during pharyngitis etc., in the food industry and perfumery.

menthol valerate (menthyl isovalerate). Acts on the central nervous system; has a vasodilating action; used in medicine.

mepacrine (acrichine, quinacrine). An acridine derivative. Properties: yellow crystalline powder with a bitter taste; soluble in water.

Uses: an antimalarial drug.

mercaptan (thioalcohol). An organic compound of the formula R-SH , where R is a radical, e.g. CH_3- , C_2H_5- , etc. Has a very disagreeable odour.

mercaptans, See *thiols*.

mercuric chloride (corrosive sublimate) HgCl_2 .

Properties: a white powder soluble in water, alcohol, ether, acetone, easy to sublime. A strong poison.

Uses: in medicine (a disinfectant), for treatment of seeds, in the manufacture of pharmaceuticals, as a wood preservative.

mercurimetry. A technique for quantitative determination of substances by titrating their solutions with mercuric salts. Mercury(II) forms stable complexes with a number of ions.

mercury Hg. A Group II element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 80, atomic mass 200.59, known from the earliest times.

Properties: a silvery liquid metal, m.p. 39°C , appreciably volatile even at room temperature, very poisonous in the vapour state. Rather nonreactive, dissolves in concentrated nitric and sulphuric acids and in *aqua regia*, easily reacts with halogens and sulphur. The oxidation states in compounds $+1$ and $+2$. Mercury dissolves a number of metals such as gold, silver, zinc, lead, tin, etc. to form amalgams.

Occurrence: not wide-spread; sometimes found in the free state, more frequently as cinnabar (mercury sulphide, HgS), which is its chief source.

Uses: in various devices (thermometers, barometers, high-vacuum pumps, relays); mercury cathodes are used in the manufacture of chlorine and alkalis, metals of high purity; mercury metal is employed in the extraction of metals, as a dropping electrode in polarography, as a catalyst in organic chemistry, in the manufacture of mercury vapour lamps, daylight lamps, etc. Mercury compounds have also found wide applications. Mercury fulminate, $\text{Hg}(\text{ONC})_2$, is a strong explosive for caps and detonators. Mercuric iodide, HgI_2 , is a bactericide. Mercury nitrates, $\text{Hg}_2(\text{NO}_3)_2$ and $\text{Hg}(\text{NO}_3)_2$, are employed in the analytical chemistry. Mercurous oxide, Hg_2O , is an unstable black solid; mercuric oxide, HgO , is a red substance used as an oxidant, in the organic synthesis, in the analytical chemistry, in the manufacture of pigments, and in medicine. Mercuric sulphide (cinnabar), HgS , is a bright-red substance used as a red pigment. Mercurous chloride, Hg_2Cl_2 (calomel) is used in calomel electrodes, as a catalyst in the organic chemistry, and as a laxative in medicine. Mercuric chloride, HgCl_2 (sublimite) (very poisonous), is employed in medicine as a strong disinfectant, in agriculture (pesticide), in the organic chemistry (catalyst), for impregnating wood, in photography, dyeing, in the manufacture of pharmaceuticals, etc.

metal [Gk *metallon*, mine]. A substance having a "metallic" lustre, ductile, and a good conductor of heat and electricity; these properties depend on the presence of free electrons in the crystal lattice of metals.

metaldehyde $(\text{CH}_3\text{CHO})_n$. A polymer of acetaldehyde in which n is usually 4 to 6. A solid fuel used to replace alcohol.

metallic bond. A type of bond characteristic of metals and intermetallic compounds: metal atoms form positively charged ions when they lose valence electrons which move comparatively freely in the lattice; a "gas" of free electrons shared by the crystal as a whole is thus formed. The bonds are not localized and do not have definite directions and for that reason, high coordination numbers, e.g. 12 or 8, frequently occur in metals. Freely moving electrons are responsible for the high electric and thermal conductivity of metals. Various types of mixing of ionic, covalent, and metallic types of bonding are possible.

metalloid. A traditional and not very accurate name for non-metals such as sulphur, nitrogen, etc. Now refers usually to elements intermediate between metals and non-metals such that form amphoteric oxides, etc., e.g. arsenic, antimony.

metallothermy. The reduction of elements from their compounds by more reactive metals at elevated temperatures, e.g. *aluminothermy*. The elements used as reducing agents are Si, usually in the form of ferrosilicon, Ca, Ba, Mg, Na, Al, etc. Metallothermy is employed in the isolation of some nonferrous and rare metals.

metallurgy [metal + Gk *-ergos*, working]. The branch of study, technology, and industry dealing with the isolation of metals from their ores.

metallurgy of ferrous metals. Steel and pig iron manufacture.

metaphosphate. A salt of metaphosphoric acid, HPO_3 (see *phosphoric acids*). Potassium and calcium metaphosphates, KPO_3 and $\text{Ca}(\text{PO}_3)_2$, are used as fertilizers.

methacrylates. Esters of methacrylic (2-methylpropenoic*, α -methylacrylic) acid, $\text{CH}_2=\text{CH}(\text{CH}_3)\text{COOH}$. Methyl acrylate, $\text{CH}_2=\text{CH}-\text{COOCH}_3$, and methyl methacrylate are of practical importance. Used in the manufacture of transparent and stable to light plastics (Plexiglas).

methane CH_4 . The simplest hydrocarbon, formed in the decomposition of organic substances in the absence of air, e.g. in coalmines and marshes. Hence its other names (marsh gas, firedamp). It is the major component of most natural gases and of gases formed in coking and hydrogenation of coal.

Properties: a colourless and odourless gas, slightly soluble in water, lighter than air, burns giving pale bluish fire; forms explosive mixtures with air. Reacts with halogens

to give halogenated methanes, e.g. $\text{CH}_4 + 3\text{Cl}_2 = \text{CHCl}_3 + 3\text{HCl}$.

Uses: fuel in industry and household, used to synthesize water gas: $\text{CH}_4 + \text{H}_2\text{O} = \text{CO} + 3\text{H}_2$, acetylene, halogenated hydrocarbons, carbon black, etc.

methanol. See *methyl alcohol*.

methenamine (hexamethylenetetramine, hexamine, urotropin). Used in the manufacture of phenol-formaldehyde resins, in the analytical chemistry, and in medicine as antiseptic.

methyl acrylate. See *methacrylates*.

methyl alcohol (methanol*, wood alcohol) CH_3OH .

Properties: a colourless liquid with a characteristic odour, miscible with water, a good solvent for many organic substances, burns giving pale fire, very poisonous (causes blindness in small amounts, may be fatal).

Derivation: by the destructive distillation of wood, whence its name "wood alcohol"; by high-pressure (5×10^7 Pa) catalytic (e.g. ZnO) synthesis from carbon monoxide and hydrogen at 300 to 600 °C: $\text{CO} + 2\text{H}_2 = \text{CH}_3\text{OH}$.

Uses: a starting material for the synthesis of formaldehyde and other organic substances, in the manufacture of dyes and lacquers.

methyl-*para*-aminophenol $\text{HO}-\langle \text{C}_6\text{H}_4 \rangle-\text{NH}-\text{CH}_3$. An organic substance whose sulphate called Metol is used in photography as developer.

methylation. The introduction of the methyl group, CH_3- , into an organic substance.

methylene blue $\text{C}_{16}\text{H}_{18}\text{N}_3\text{SCl}$. An organic dye, used for dyeing cotton, wool, and silk. Employed in the analytical chemistry (the determination of chlorate and perchlorate anions, mercury and tin cations) and in medicine.

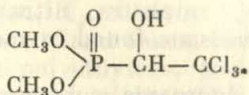
methyl methacrylate. See *methacrylates*.

methyl orange. An organic dye whose aqueous solution is used in the analytical chemistry as acid-base indicator (red in acid and yellow in alkaline media).

methyl violet. An organic dye used in the manufacture of ink, typewriter ribbons, of limited applicability for dyeing wool and silk. Also used in the analytical chemistry to determine certain ions.

Metol. See methyl-*para*-aminophenol.

metrifonate



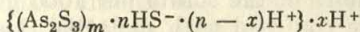
An insecticide used against gad-fly of cattle, also effective against flies, bugs, pests. Soluble in water, only slightly toxic.

mica. A group of aluminium silicates of a complex structure. Can be split into very thin sheets with a smooth surface. Natural and synthetic varieties are known. Widely used as materials for insulators.

Micarta. Trademark for a group of laminated plastics made of paper and like materials bonded by phenol-formaldehyde or analogous resins.

Uses: electric and thermal insulation; structural material.

micelle. A particle in colloidal systems, consists of an insoluble nucleus of exceedingly small dimensions surrounded by a stabilizing layer of adsorbed ions and solvent molecules. For example, the structure of the micelle of arsenic sulphide is as follows:



Micelle dimensions range from 10^{-5} to 10^{-7} cm on an average.

microcrystalloscopy. A method for detecting inorganic and organic substances by the formation of characteristic crystalline precipitates under the action of analytical reagents. The crystals formed are examined with the help of a microscope.

micronutrient. A chemical element essential to plants, animals, and microorganisms in very small amounts, e.g. B, Cu, Mn, Zn, Mo, Co, I, etc. Found in many enzymes.

mineral. A natural substance near uniform in its chemical composition and physical properties. At present, more than 2000 minerals have been registered. According to their chemical compositions minerals belong to various classes of compounds, i.e. free elements (diamond, graphite, sulphur, gold, platinum, silver, copper, mercury, etc.), metal and non-metal sulphides (pyrite, galena, molybdenite, cinnabar, antimonite or stibnite, chalcopyrite or copper pyrites, arsenopyrite, etc.), salts of arsenic and antimonie etc. acids, halogen compounds, oxides

and hydroxides (quartz, pyrolusite, corundum, bauxite, etc.), carbonates, sulphates, nitrates, silicates, phosphates, etc. Minerals are found in rocks, ores, meteorites, etc.

mineral fertilizers. Inorganic substances containing compounds of elements essential to plant life; more particularly, compounds of nitrogen, phosphorus, potassium, etc.

mineralogy. The branch of study dealing with minerals, their chemical composition, properties, the conditions of their formation and existence in nature.

mineral resources. Minerals and fossils that are used as starting materials in the manufacture of acids, alkalis, salts, fertilizers, and other chemical products.

minerals. Natural formations of inorganic or organic origin used after processing or in the form in which they occur in nature in various fields of industry. Can be solid, liquid, or gaseous. According to their use can be combustible (coal, oil shale, petroleum, natural gases), non-metallic, and ores of metals.

mirabilite. See *Glauber's salt*.

molality. The concentration of a solution measured as the number of moles of the solute per 1000 g of the solvent, should not be confused with molarity. In SI units, expressed as the number of moles of the solute per 1 m^3 of the solvent (mole/m^3). See also *concentration*.

molar volume. The volume of 1 mole of a gas under normal conditions, 22.4 litres.

mole. A unit of the amount of a substance, adopted by the 14th General Conference on Weights and Measures (1971) as the seventh basic SI unit. Mole is the amount of a substance that contains as many elementary units (atoms, molecules, ions, electrons, etc.) as there are atoms in 0.012 kg of carbon-12. A number of derivative units, so called molar units, are based on the mole unit, e.g. molar mass (kg/mole), molar volume (m^3/mole), molar internal energy (J/mole), molar concentration (mole/m^3), etc.

molecular weight. Relative molecular mass, the sum of the atomic masses of all the atoms contained in a given molecule measured in atomic mass units.

molecule [*L moles*, a mass]. The smallest portion of a simple or complex substance retaining the principal chemical properties of the substance. Any substance contains the same molecules independently of the method of its prep-

aration. The number of atoms in a molecule ranges from 2 (in hydrogen, H_2 , chlorine, Cl_2 , carbon monoxide, CO, etc.) to hundreds and thousands (in macromolecules such as occur in polyethylene, proteins, etc.).

molybdenite (molybdenum glance) MoS_2 . A soft lead-grey mineral with metallic lustre. The principal ore of molybdenum. Molybdenite is a semiconductor used in the manufacture of rectifiers.

molybdenum [Gk *molybdos*, lead] Mo. A Group VI element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 42, atomic mass 95.94. Recognized by Scheele in 1778.

Properties: a light-grey, high-melting (m.p. $2620^\circ C$), very hard metal. The principal oxidation states are +6, +5, +3; stable in the air at room temperature, undergoes oxidation to MoO_3 if heated to $600^\circ C$; the oxide, MoO_3 , gives a series of acids of the type $nMoO_3 \cdot mH_2O$ whose salts are called molybdates: alkali solutions contain isolated MoO_4^{2-} anions, which combine as acidity increases to form isopolymolybdate anions, e.g. $Mo_2O_7^{2-}$, or heteropolymolybdates if the solution contains phosphate, silicate, arsenate anions, e.g. ammonium phosphomolybdate, $(NH_4)_3H_4[P(Mo_2O_7)_6] \cdot 4H_2O$.

Derivation: from molybdenite, MoS_2 .

Uses: as alloying component of steels, in electrical and radio devices. Molybdenum is a microelement.

monazite. A mineral containing rare earth metal phosphates, mainly phosphates of cerium family metals, $(Ce, La)PO_4$. Together with rare earths (more than 50%) contains ThO_2 (5 to 10%), sometimes U_3O_8 (up to 1%). Colour reddish-brown, resinous lustre, brittle. Used as a source of rare earth metals and thorium.

Monel. Trademark for a nickel-copper alloy containing up to 30% copper. It has high mechanical properties and resistance to corrosion; ductile. Used in the chemical, petroleum, shipbuilding industries, in the manufacture of medical and other instruments.

monomer. A starting material for the synthesis of a high-molecular-weight compound (polymer). Monomers may be compounds which can polymerize because of the presence of double, triple bonds, aldehyde and hydroxyl groups, etc. Purity of monomers is a very important factor in the manufacture of polymers.

monomolecular layer. A layer one molecule thick, formed at interfaces, e.g. as a result of adsorption.

monosaccharide. A simple sugar (monose), a hydroxyaldehyde or hydroxyketone. Examples are glucose, fructose, etc. Cannot be hydrolyzed.

morphine [Gk *Morpheus*, the god of dreams]. The alkaloid of opium, extracted from unripe poppy-seed. Morphine hydrochloride is used in medicine to induce sleep and relieve pain. A narcotic.

mullite. Aluminium silicate, $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$, found in nature. Fused mullite is used in the manufacture of very high-temperature refractories rich in alumina (crucibles, slabs, bricks).

muscovite (white mica, potassium mica). A mineral, $\text{KAl}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$. A variety of muscovite containing up to 4% Cr_2O_3 which makes it bright-green is called fuchsite. Used in electrical and radio devices, as windows of furnaces, boilers, etc.

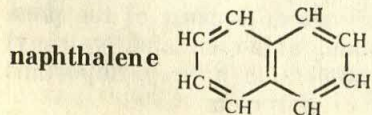
mustard gas (dichlorodiethyl sulphide) $(\text{ClCH}_2\text{CH}_2)_2\text{S}$. A liquid with a mustard odour, b.p. 217°C . A vesicant war gas, causes conjunctivitis and heavy intoxication. Made from ethylene.

myosin [Gk *mys*, *myos*, a muscle]. A protein present in contractile muscles which causes the loss of one phosphate group from ATP (adenosine triphosphate) to release energy necessary for muscle contraction.

N

napalm. A mixture of a liquid fuel and aluminium salts of naphthenic and fatty acids which make gasoline thicken or jelly.

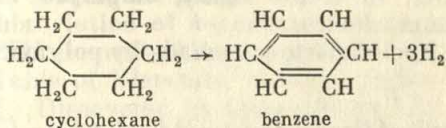
Uses: in flame throwers and fire bombs; if contains light metal alloys, e.g. sodium alloys, the mixture ignites spontaneously when brought in contact with water or snow.



A solid crystalline sub-

stance with a characteristic odour, insoluble in water, very soluble in benzene and ether; resembles benzene in its chemical properties: easy to nitrate, sulphate, reacts with halogens, but more reactive than benzene. Obtained from bituminous coal-tar oils. Naphthalene derivatives are used in the manufacture of dyes and explosives, in medicine, and as insecticides.

naphthene. A cycloparaffin hydrocarbon. Naphthenes resemble saturated hydrocarbons in their chemical properties; occur in petroleum. Naphthenes are starting materials for the preparation of aromatic hydrocarbons by catalytic cracking, e.g.



Cyclohexane is the most important compound of the series; it is used in the manufacture of caprolactam, adipic acid, and other materials for the production of synthetic fibres.

naphthol. Any of naphthalene hydroxyderivatives, $\text{C}_{10}\text{H}_{8-n}(\text{OH})_n$, where n is 1, 2, 3, or more. Has properties similar to phenols of the benzene series. Naphthols and their derivatives are used on a large scale in the production of dyes and intermediates of the organic synthesis.

narcotic drug [Gk *narkoun*, to benumb]. Any of a group of substances used in medicine to relieve pain or induce sleep (chloroform, ether, nitrous oxide, etc.) and substances causing drowsiness and having an intoxicating and stupefying action, as ethanol, morphine, cocaine, etc.

natural gases. Methane, CH_4 , and other saturated hydrocarbons accompanying it. An inexpensive and high-heating fuel.

neodymium [Gk *neos*, new + *didimos*, a twin] Nd. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 60, atomic mass 144.24, belongs with lanthanides. Discovered in 1885 by Welsbach.

Properties: a silvery metal. An analogue of other lanthanides, the oxidation state in compounds +3; salts have pink colouration.

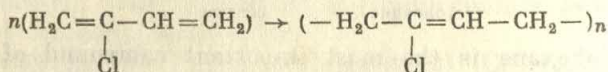
Uses: as an alloying component, in electronics, in the manufacture of coloured glass, porcelain, etc.

neon [Gk *neos*, new] Ne. A Group VIII element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 10, atomic mass 20.179, an inert (noble) gas. Discovered in 1898 by Ramsay and Travers. A monoatomic gas, does not participate in usual reactions. The hydrate, $\text{Ne} \cdot 6\text{H}_2\text{O}$, and some other compounds with bonds of molecular nature were isolated.

Derivation: by distillation of air.

Uses: filling incandescent lamps, luminescent electric tubes (gives red luminescence and therefore used in advertizing, in traffic signs), employed in electronics and vacuum devices.

neoprene. A line of elastomers made by polymerizing chloroprene:



Used in the manufacture of belts, hoses, electrical insulators.

nepheline (nephelite). A rock mineral, sodium (potassium) aluminium orthosilicate, $(\text{Na}, \text{K})\text{AlSiO}_4$. Used as an aluminium ore, in the manufacture of soda, glass, leather. Found in large amounts in apatite waste.

nephelometry [Gk *nephele*, a cloud]. The determination of the concentration of a substance from the intensity of light scattered by suspended particles. Nephelometers enable molecular masses of polymers to be determined.

neptunium [after planet Neptune, next to Uranus] Np. The first of synthetic radioactive elements, discovered by McMillan and Abelson in 1940. Atomic number 93, an actinide; the longest lived isotope is ^{237}Np ($T_{1/2} = 2 \times 10^6$ years). Found in uranium ores in negligible amounts. A silvery metal, the oxidation states in compounds +3, +4, +5, +6, +7. Aqueous solutions of neptunium compounds contain the ions Np^{3+} , Np^{4+} , NpO_2^+ , and NpO_2^{2+} . First made by irradiating uranium with neutrons, whence its name.

Nessler's reagent. A solution of $\text{K}_2[\text{HgI}_4]$ in KOH. Reacts with ammonia and ammonium salts to give a brown-red precipitate. Used in detecting and determining ammonia

and nitrogen which should first be converted to ammonia or an ammonium salt.

neutralization [L *neuter*, neither]. The interaction of acids with bases with the formation of salts and water, e.g. $\text{HCl} + \text{NaOH} = \text{NaCl} + \text{H}_2\text{O}$; in the ionic form the equation is written as $\text{H}^+ + \text{OH}^- = \text{H}_2\text{O}$. The solution turns neutral if the reagents are a strong base and a strong acid. The most important titrimetric techniques are based on the neutralization reaction.

Nichrome. Trademark for an alloy containing 60 to 80% nickel and 10 to 25% chromium. Exhibits high heat and electrical resistance. Used in the manufacture of rheostats and various heating elements.

nickel [Sw abbreviation of *kopparnickel*, false copper] Ni. A Group VIII element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 28, atomic mass 58.71. Discovered by Cronstedt in 1751.

Properties: a silvery white metal, malleable and tenacious, ferromagnetic. Moderately active. Does not undergo oxidation at room temperature. The oxidation states in compounds +2, +3. Readily forms complexes.

Occurrence: in compounds with sulphur, oxygen, arsenic, etc. Sulphide copper-nickel ores also contain gold, silver, cobalt, and platinum metals.

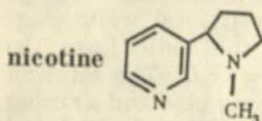
Uses: in the manufacture of special kinds of steel and alloys; some nickel alloys are heat-resistant, stable to corrosion and have useful mechanical, magnetic, and electric properties, e.g. stainless steels containing chromium and nickel, electrotechnical alloys such as constantan, Manganin, Nichrome, nickeline, and Chromel; nickel is used for nickel plating, in large amounts in the manufacture of alkaline (Edison) storage batteries, special equipment for the chemical industry, and as a catalyst.

nickeline. An alloy of copper and nickel containing 25 to 30% nickel and admixtures of manganese, iron, and zinc; has a high electrical resistance, used in the manufacture of rheostats.

nickel plating. A process for the production of nickel coatings on metal objects to prevent corrosion and improve the finish.

nickel silver. Nickel alloys containing copper, zinc, etc. Resistant to corrosion. Used for coinage, in the manu-

facture of high-precision mechanical devices, medical instruments, table cutlery, etc.



An alkaloid from tobacco, a

strong poison affecting the nervous system. Nicotine stimulates glandular activity and causes constriction of blood vessels and therefore increases blood pressure. Addiction to smoking results in chronic intoxication with nicotine. Nicotine sulphate is used in agriculture as insecticide.

nikethamide (N,N-diethylnicotinamide, diethylamide of pyridine-3-carboxylic acid). A colourless to pale yellow liquid with a characteristic odour. Stimulates central nervous system, respiration, heart activity. Has a similar to camphor action on organisms. Used in medicine.

niobium [L *Niobe*, daughter of Tantalus: from association with tantalum] Nb. A Group V element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 41, atomic mass 92.906. One stable isotope, ^{93}Nb . Discovered in 1801 by Hatchett.

Properties: a grey-white high-melting metal stable in the air. Resembles tantalum in its chemical properties, the most stable oxidation state +5. Insoluble in acids except for hydrofluoric acid. The oxide, Nb_2O_5 , shows acidic properties.

Occurrence: accompanies tantalum.

Uses: the principal component of many heat- and corrosion-resistant alloys. Niobium and its alloys are mainly used in nuclear energy devices, electronics, in the manufacture of apparatus for the chemical industry, jet engines, in the rocket engineering, in vacuum systems.

nitrate. A salt of nitric acid. Nitrates are stable at room temperature, they are prepared by the action of HNO_3 on metals, metal oxides, hydroxides, and salts. The major uses are: fertilizers (nitre and its analogues), explosives (ammonites), etc.

nitration. The introduction of the nitro group, NO_2 , into organic molecules under the action of nitric acid, nitrogen dioxide, and other nitrating agents.

nitric acid HNO_3 .

Properties: a colourless liquid with a pungent odour, attracts moisture from the air, b.p. 84°C ; miscible with water. Dilute nitric acid shows all the properties of monobasic acids. Concentrated nitric acid (96 to 98%) is a reddish-brown liquid because of the presence of NO_2 . In the light or when heated decomposes to NO_2 , O_2 , and H_2O . Concentrated nitric acid is one of the strongest oxidizing agents, dissolves almost all metals except for gold, platinum, iridium, and rhodium with the formation of metal nitrates and evolution of nitrogen oxides. Aluminium, iron, and chromium readily react with dilute nitric acid but remain unattacked by concentrated acid because of the formation of a thin surface protecting film of metal oxides. Nitric acid reacts with many non-metals and organic substances.

Derivation: in industry from ammonia.

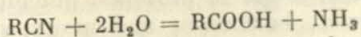
Uses: the production of nitrogen fertilizers, explosives, pharmaceuticals, dyes, plastics, synthetic fibre, as oxidizer in jet engines, etc.

nitrides. Mostly compounds of nitrogen with metals, e.g. Na_3N , Mg_3N_2 , AlN , BN , TiN . Formed at high temperatures. Have a number of properties important for the modern technology: they are fire- and heat-resistant, stable to the action of acids and alkalis, good conductors of heat and electricity. Used in alloys.

nitriding of steel. A process in which steel objects are heated at 480 to 650°C in the atmosphere of ammonia. Atomic nitrogen formed under these conditions is adsorbed on the metal surface with the formation of iron and alloying element nitrides. Nitriding of ferrous alloys increases their hardness, durability, and stability to corrosion.

nitrification. The oxidation of ammonia to nitric acid via the formation of nitrous acid under the action of nitrobacteria. The process is important for fertilizing soil.

nitrile. An organic compound containing the $-\text{CN}$ group, e.g. acetonitrile, $\text{H}_3\text{C}-\text{CN}$. The interaction of nitriles with water



is one of the methods of the synthesis of carboxylic acids.

nitrite. A salt of nitrous acid, HNO_2 . Nitrites are less stable than nitrates; used in the manufacture of azodyes and in medicine.

nitrobenzene $C_6H_5NO_2$. The simplest aromatic nitrocompound. Properties: oily liquid with a bitter almond odour, poisonous.

Derivation: by nitrating benzene with a mixture of concentrated HNO_3 and H_2SO_4 .

Uses: aniline production.

nitrocellulose (cellulose nitrate, nitrocotton). Esters of cellulose and nitric acid, e.g. cellulose trinitrate, $C_6H_7O_2(ONO_2)_3$.

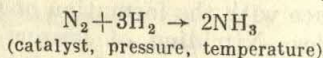
Uses: the manufacture of nitro lacquers (fast drying), photographic film, Celluloid, pyroxylin, collodion.

nitrocompounds. Organic compounds containing the nitro group, $-NO_2$, e.g. nitromethane, CH_3NO_2 ; nitrobenzene, $C_6H_5NO_2$. Usually made by nitrating. Used in the manufacture of dyes, pharmaceuticals, and explosives.

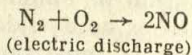
nitrogen [Gk *nitron*, native soda, natron] N. A Group V element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 7, atomic mass 14.0067, two stable isotopes, ^{14}N (99.635%) and ^{15}N . Discovered by D. Rutherford in 1772.

Properties: a colourless gas, odourless, slightly soluble in water, lighter than air, m.p. $-210^\circ C$, b.p. $-195.8^\circ C$.

Nitrogen molecules are diatomic with a strong triple bond between the atoms, $:N \equiv N:$. The oxidation states in compounds range from -3 to $+5$: $N^{-3}H_3$, $N_2^{-2}H_4$, $N^{-1}H_2OH$, $N^{-1}H_2$, $N_2^{+1}O$, $N^{+2}O$, $N^{+4}O_2$, $N_2^{+5}O_5$. Almost unreactive at room temperature. At elevated temperatures combines with active metals to give nitrides, e.g. Ca_3N_2 . Under certain conditions reacts with hydrogen



and oxygen



Forms several oxides (see *nitrogen oxides*).

Occurrence: the atmosphere contains 78 vol.% N_2 , occurs as nitre, found in proteins, nucleic acids, chlorophyll, enzymes, hormones, and many vitamins.

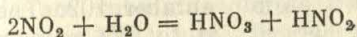
Derivation: by fractional distillation of liquefied air.

Uses: mainly in the synthesis of ammonia. Liquid nitrogen is used as a source of cold, free nitrogen as an inert atmosphere for certain chemical processes, for filling

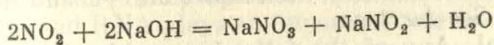
incandescent lamps, for electric welding of metals. Air nitrogen is the chief nitrogen source for the manufacture of nitrogen fertilizers.

nitrogen fertilizers. Inorganic and organic compounds containing nitrogen put in the soil to make it fertile. Mineral nitrogen fertilizers include amide, ammonia, and nitrate fertilizers. Prepared mostly from synthetic ammonia.

nitrogen oxides. Compounds of nitrogen with oxygen. Nitrous oxide (nitrogen monoxide, laughing gas), N_2O , is a colourless gas with a weak odour, soluble in water, does not react with water and solutions of acids and bases; decomposes to nitrogen and oxygen when heated; has a stimulating action at high concentrations, used as a weak anaesthetic in medicine. Nitric oxide, NO , is a colourless gas sparingly soluble in water, does not react with water and solutions of bases and acids; a very reactive compound, readily forms addition compounds with a number of salts (nitrososalts), halogens (e.g. nitrosyl chloride, $NOCl$), and organic compounds; combines with oxygen without heating to give NO_2 . Nitric oxide is formed in catalytic oxidation of ammonia in the synthesis of nitric acid. Nitrous anhydride, N_2O_3 , is unstable under usual conditions, reacts with water to give nitrous acid, HNO_2 . Nitrogen dioxide (nitrogen tetroxide), NO_2 , is a red-brown gas, poisonous, heavier than air, easy to liquefy, at room temperature exists as an equilibrium mixture of NO_2 and its colourless dimer, N_2O_4 . Reacts with water:

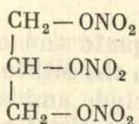


and solutions of alkalis



NO_2 is a strong oxidizer; many substances such as carbon, sulphur, phosphorus, organic compounds can burn in the atmosphere of NO_2 ; it oxidizes SO_2 to SO_3 as in the chamber process for manufacturing sulphuric acid. NO_2 has an irritating action on respiratory organs, in large concentrations can cause emphysema. Nitric anhydride, N_2O_5 , is a colourless crystalline solid, readily decomposes to NO_2 and O_2 ; a strong oxidizer, dissolves in water with the formation of nitric acid, HNO_3 .

nitroglycerin (glyceryl trinitrate, explosive oil). An ester of glycerol and nitric acid,



Properties: a heavy oily liquid, insoluble in water, poisonous, explodes when shocked or heated.

Uses: the manufacture of explosives (dynamites). Solutions in ethanol (1%) are used in medicine for dilating blood vessels.

nitrophosphate. A complex fertilizer containing nitrogen, phosphorus, and usually potassium. Generally obtained by the action of nitric acid or a mixture of nitric and sulphuric or phosphoric acids on phosphate rock followed by the neutralization with ammonia and addition of potassium salts.

nitrosocompounds. Compounds containing the $-\text{N}=\text{O}$ group, e.g. nitrosobenzene, $\text{C}_6\text{H}_5\text{NO}$.

nitrous acid HNO_2 . A weak monobasic acid, exists only in dilute aqueous solutions which decompose when heated with the evolution of NO and NO_2 . Can oxidize certain species, e.g. I^- , and undergo oxidation to HNO_3 under the action of strong oxidizing agents such as H_2O_2 and KMnO_4 . Metal salts of nitrous acid, nitrites, are used in the organic synthesis.

nobelium (after A. Nobel) No. A transuranic element of the actinide series, atomic number 102. The isotopes with the mass numbers of 251 to 259 were synthesized; the longest lived isotope, ^{259}No , decays with a half-life of about 1.5 h. The oxidation states are +2 and +3.

noble gas. See *inert gas*.

noble metal. Any of the following: gold, silver, mercury, platinum, palladium, iridium, rhodium, ruthenium, and osmium.

nomenclature [L *nomen*, name + *calare*, to call]. The system of names of chemical elements and compounds used in chemistry to remove ambiguity in designating particular substances in written and spoken languages.

non-metal (formerly called metalloid). A simple substance lacking the properties characteristic of metals (glitter, malleability, electric and thermal conductivity). Many

non-metals are gases under usual conditions. Non-metals also differ from metals in their chemical properties: their higher oxides are usually acidic while the lower oxides of metals are basic.

normality. A form of expressing solution concentrations by the number of equivalents of a solute per litre of a solution, very common in the analytical chemistry.

Norway saltpeter. See *ammonium salts*.

Novaminsulphon (analgin). A pharmaceutical of the antipyrine series, acts to lower the body temperature, reduce fever, and relieve pain.

Novocaine. A trademark for a brand of procaine hydrochloride (see *procaine*).

nuclear fuel. Uranium and plutonium isotopes with odd mass numbers (^{233}U , ^{235}U , ^{239}Pu , ^{241}Pu) whose nuclei undergo fission under the action of slow neutrons. Used in nuclear energy devices.

nuclear magnetic resonance, NMR. The resonance absorption of radio-frequency electromagnetic radiation by substances in a permanent magnetic field caused by the magnetic properties of nuclei. Discovered in 1946.

nucleic acids [L *nucleus*, a nut, kernel]. High-molecular-weight organic substances (molecular masses from hundred thousands to millions), constituents of nucleoproteins. Play an important role in living activity of all organisms. Incorporate a large number of mononucleotides containing phosphoric acid, carbohydrates (ribose and deoxyribose), and purine and pyrimidine bases. Nucleic acids are subdivided into two types, deoxyribonucleic acid (DNA) and ribonucleic acid (RNA); the former is found in chromosomes of nuclei of all cells, and the latter in cytoplasm. DNA is responsible for heredity, and RNA plays an important role in the synthesis of proteins.

nucleoprotein. Any of a group of compound proteins found in the nucleus and cytoplasm of a cell and consisting of simple proteins combined with nucleic acids.

nucleotide. A compound organic substance incorporating phosphoric acid, a sugar (ribose or deoxyribose), and a nitrogenous base. Nucleotides are important for metabolism and energy exchange, occur in nucleic acids, various coenzymes, etc.

nylon. A generic term for any long-chain polymeric amide which is capable of being formed into a filament. Nylon fibre is superior to natural silk in strength. It is used in the manufacture of cord, fishing nets, conveyer belts, knitwear, etc.



occlusion [*L. claudere*, to shut]. The capture of admixtures from solutions by precipitating particles; typical for processes characterized by rapid growth of precipitate particles. Unlike adsorption occlusion occurs in the bulk of precipitate crystals. Absorption of gases by metals is a kind of occlusion.

ocher. Any of native mineral pigments composed of ferric hydroxide with alumina or other metal oxides as admixtures. Ochres are light-yellow or brown.

octane C_8H_{18} . Any of the 18 isomers of the composition indicated. A saturated hydrocarbon. The isomer $(CH_3)_3C-CH_2-CH(CH_3)_2$ called isooctane is characterized by the lowest degree of knocking, its octane number is taken to be 100.

octane number. A number indicating the degree of knocking of light motor fuels (gasoline) used in internal combustion engines, measured with reference to standard mixtures of isooctane (octane number 100) and *n*-heptane (octane number 0) taken in ratios from 100 : 0 to 0 : 100.

oil shale. A sedimentary rock containing organic combustible material, used as fuel of local importance, as a starting material for the manufacture of liquid fuels, binders, bitumens, oils, phenols, benzene, toluene, xylenes, naphthenes, etc.

olefin (olefine, alkene). A hydrocarbon of the ethylene series, C_nH_{2n} .

oleic acid (red oil) $CH_3(CH_2)_7CH=CH(CH_2)_7COOH$. An unsaturated fatty acid, found in many vegetable and animal fats in the form of esters (as glycerides). Used in the manufacture of soap.

oleum. See *sulphuric acid*, fuming.

oligosaccharide [*Gk. oligos*, small]. A polymeric carbohydrate composed of a small number, 2 to 10, of monosaccharide residues.

olivine (chrysolite) $(\text{Mg}, \text{Fe})_2\text{SiO}_4$. A rock of olive or yellowish-green colour, a source of MgO . A transparent gem variety is called peridot.

opal. A native amorphous hydrated silica, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$. Colour white, yellow, or brown. Includes several varieties, e.g. precious opal with a brilliant play of colours.

open-hearth process, Siemens-Martin process. A process for steel manufacture suggested by the French metallurgist Martin in 1864. Unlike the Bessemer process, carried out in a furnace with smelting by hot producer gases. The open-hearth process has the advantage of providing the possibility to remove undesired admixtures, take assays, and add needed components to produce special kinds of steel during smelting.

opium. A drug prepared by drying the juice of unripe seed capsules of some kinds of poppy. Contains morphine, papaverine, codeine, and other alkaloids. Used in medicine to relieve pain, either as a whole (tetrapon) or in the form of individual alkaloids. A narcotic.

optimum conditions. The most favourable conditions for some organism or process.

orbitals molecular. See *theory of molecular orbitals*.

ore. An aggregation of minerals from which one or more metals can be extracted at a profit. All minerals but those containing the metal(s) in question are called waste rock. The term is also applied to rocks containing certain non-metals (sulphur, asbestos, etc.).

organic acids. See *carboxylic acids*.

organic chemistry. The chemistry of carbon compounds, developed into a separate discipline in the 19th century. At present, various branches of organic chemistry have acquired the status of independent research fields, e.g. organoelement chemistry, the chemistry of naturally occurring substances, polymers, antibiotics, vitamins, hormones, dyes, stereochemistry, etc. There are, however, general laws of the organic chemistry which hold with all organic subjects. Butlerov's theory of the structure of organic substances played an important part in the development of the organic chemistry (1861). At present, more than 3 000 000 organic compounds are known.

organic fertilizers. Fertilizers containing elements essential to plants mainly in the form of organic substances (ma-

nure, composts, peat, straw, slime, green manure, silt, industrial and agricultural wastes, etc.).

organoelement compounds. Organic compounds containing carbon-element bonds other than C—N, C—O, C—S, or C—Hal, e.g. C—Mg, C—Si, C—Ge. See also *organometallic compounds*.

organogen. A term of historical value referred to the principal chemical elements found in organic substances, viz. carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus.

organomercury compounds. Chemical compounds containing one or more mercury atoms bound directly to carbon, e.g. $\text{CH}_3\text{—Hg—CH}_3$ or $\text{CH}_3\text{—Hg—Cl}$. Used in medicine, in the organic synthesis, etc.

organometallic compounds (organometallics). Organic compounds in which a metal is attached directly to carbon, e.g. $(\text{CH}_3)_3\text{Al}$, $\text{C}_2\text{H}_5\text{MgI}$. Organometallics are widely used in diverse syntheses and in various industrial fields.

organosilicon compounds. Compounds containing carbon-silicon bonds, used in the manufacture of organosilicon polymers.

ornithine (2,5-diaminovaleric acid, 2,5-diaminopentanoic acid*) $\text{NH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{NH}_2)\text{COOH}$. An amino acid, plays an important part in urea biosynthesis. The elimination of carbon dioxide from ornithine during putrefaction of a dead body results in the formation of putrescine (1,4-butanediamine*).

ortho-, meta-, para- [Gk *orthos*, straight; Gk *meta*, after, between; Gk *para*-, at the side of]. Prefixes used in the organic chemistry to designate the positions of two similar or dissimilar substituents in the benzene ring with respect to each other. In the inorganic chemistry, the prefixes ortho- and meta- are used to name two forms of an acid with different numbers of hydroxy groups (orthoacids contain the larger and meta- the smaller number of such groups), e.g. orthophosphoric acid, H_3PO_4 , and metaphosphoric acid, HPO_3 . See also *isomers*.

osmium [Gk *osme*, odour; so called because of irritating smell of OsO_4] Os. A Group VIII element of the 6th period of the Mendeleev Periodic Table, atomic number 76, atomic mass 190.2. Discovered in 1804 by Tennant. A platinum family metal.

Properties: tin-white metal with a bluish cast, the heavi-

est of all the metals known, hard, brittle. Gives OsO_4 when heated in the air. The most stable oxidation states are +4, +6, and +8. Like other platinum metals readily forms complex compounds.

Occurrence: as iridosmine (a natural alloy with iridium).

Uses: because of the high hardness and corrosion resistance the metal and its alloys with other platinum metals and also with Co and W are used in the manufacture of precision measurement instruments. Osmium and its compounds, e.g. OsO_4 , are good catalysts.

oxalate. A salt of oxalic acid, $\text{H}_2\text{C}_2\text{O}_4$.

oxalic acid $\text{H}_2\text{C}_2\text{O}_4$. The simplest dibasic acid of the saturated series, a strong carboxylic acid; crystallizes with two water molecules. Its salts such as calcium and potassium oxalates are found in many plants (sorrel, woodsorrel). The acid and the oxalate anion, $\text{C}_2\text{O}_4^{2-}$, have a reducing action (turn solutions of KMnO_4 colourless). Poisonous. Uses: in the analytical chemistry used as a primary standard to standardize solutions in redox titration, to precipitate and determine calcium, rare earth elements, thorium; also used in the manufacture of dyes, ink, in a number of industrial syntheses.

oxidation. The loss of electrons by a substance undergoing oxidation (the reducing agent). The electrons released by atoms or molecules of one compound are added to atoms or molecules of another one called an oxidizing agent. The oxidation of one of the participants (the reducing agent) is thus accompanied by the reduction of another one (the oxidizing agent), i.e. a redox reaction. The oxidation results in an increase of the positive valence (the oxidation state) of the oxidized element. Earlier the term was only referred to the addition of oxygen, e.g. the formation of oxides, $2\text{Cu} + \text{O}_2 = 2\text{CuO}$ or burning of methane, $\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$. At present, the combination with oxygen is regarded as a particular oxidation reaction. The oxidation is accompanied by release of energy; it is a very common process in nature (burning, rusting, putrefaction, etc.).

oxidation number. See *oxidation state*.

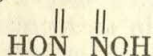
oxidation state (oxidation number). An auxiliary quantity used to write down the oxidation, reduction, and redox reactions. Corresponds to the charge of an ion or formal charge of an atom in a molecule or chemical formal unit,

e.g. NaCl , $\text{Mg}(\overset{+2}{\text{Cl}}\overset{-1}{})_2$, H^{+1} (hydrogen ion), $\overset{-3}{\text{N}}(\overset{+1}{\text{H}})_3$, $\overset{+2}{\text{C}}\overset{-2}{\text{O}}$, $\overset{+1}{\text{Cl}}\overset{-1}{\text{F}}$, $\overset{-4}{\text{C}}(\overset{+1}{\text{H}})_4$, $\overset{+4}{\text{C}}(\overset{-2}{\text{O}})_2$, $\overset{+1}{\text{K}}\overset{+7}{\text{Mn}}\overset{-2}{\text{O}}_4$. The numbers given above the symbols of the chemical elements are their oxidation states. The oxidation state of an atom in a simple compound is zero, e.g. H_2^0 , O_2^0 , C^0 (diamond or graphite). The notion of the oxidation state is inapplicable to non-stoichiometric compounds (KC_8 , Mo_5Si_3 , Nb_3B_4 , etc.).

oxide. An element compound with oxygen where oxygen atoms are not linked with each other. Nomenclature: oxides of the same element are named according to element's valence state, e.g. ferric oxide, Fe_2O_3 , ferrous oxide, FeO ; or according to the number of oxygen atoms, e.g. carbon monoxide, CO , carbon dioxide, CO_2 . The valence state of an element may be indicated in parentheses by Roman numerals, e.g. iron(III) oxide, Fe_2O_3 . Binary compounds with oxygen containing O—O bonds are called peroxides, e.g. K_2O_2 , potassium peroxide, superoxides, e.g. KO_2 , potassium superoxide. Other prefixes used with oxygen compounds are sesqui- (K_2O_3 , potassium sesquioxide), sub- (C_3O_2 , carbon suboxide), etc. Depending on the chemical properties oxides are classified as salt forming oxides including basic (Na_2O , CuO) and acidic (SO_3 , NO_2) oxides, amphoteric oxides (ZnO , Al_2O_3), and oxides forming no salts (e.g. CO , NO).

oxide coating. A coating of a metal surface with a protective oxide film to prevent corrosion or for decorative purposes.

oxime. An organic substance containing the $=\text{NOH}$ group, e.g. dimethylglyoxime, $\text{H}_3\text{C}-\text{C}=\text{C}-\text{CH}_3$, used for the



quantitative determination of Ni^{2+} , Pd^{2+} , and Fe^{2+} .

oxine. See *8-hydroxyquinoline*.

oxygen [Gk *oxys*, sharp, acid] O. A Group VI element of the 2nd period of the Mendeleev Periodic Table of Elements, atomic number 8, atomic mass 15.9994. Occurs in nature as a mixture of three isotopes, ^{16}O (99.759%), ^{17}O (0.037%), and ^{18}O (0.204%). Discovered by Scheele in 1771 and, independently, by Priestley in 1774.

Properties: a diatomic gas, O_2 , colourless and odourless, b.p. -182.98°C , m.p. -218.7°C , gives ozone, O_3 , under the action of electric discharge. Slightly soluble in water. Effectively absorbed by charcoal and molten

noble metals. Forms compounds with all the chemical elements except for light inert gases; reacts directly with most elements. The oxidation state in compounds -2 . Readily oxidizes organic substances.

Occurrence: the most abundant element, forms 21% of the atmosphere by volume, contained in bound state in water, sand, alumina, rocks, ores, etc.

Derivation: from air by liquefaction.

Uses: various applications in the chemical industry, welding and cutting of metals, in medicine, in aviation, submarines. Liquid oxygen is used as an oxidant in rocket fuels. Oxygen is essential to all living organisms.

oxyliquit. An explosive made by impregnating a porous solid fuel with liquid oxygen, used in mining.

ozocerite [Gk *ozein*, to smell + *keros*, wax] (mineral wax, fossil wax). A bitumen mineral, a mixture of high-molecular-weight solid paraffins, waxlike, with a kerosene smell. Purified ozocerite is called ceresin.

Uses: electric insulation, lubricating compositions, greases for technical and medical purposes.

ozone [Gk *ozein*, to smell] O_3 . A simple substance, an allotropic form of oxygen.

Properties: a gas with a characteristic odour, unstable; a strong oxidizing agent, reacts with most metals to give the corresponding oxides, destroys rubber.

Occurrence: formed in the atmosphere under the action of thunderstorm electricity, ultraviolet irradiation.

Derivation: by subjecting air or oxygen to a silent electric discharge in special apparatus (ozonizers).

Uses: as an oxidizing agent for air purification and conditioning, decontamination of drinking water, in the manufacture of some organic substances (camphor, vanilline, fatty acids, etc.).

P

palladium [Gk *Pallas*, the goddess] Pd. A Group VIII element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 46, atomic mass 106.4, a metal of the platinum family. Discovered by Wollaston in 1803 and named after planetoid Pallas.

Properties: a silvery white metal, melts at a lower temperature (m.p. 1555 °C) than all the other platinum metals. In its chemical behaviour resembles platinum but is somewhat more reactive, dissolves in concentrated HNO_3 . The oxidation states in compounds +2, +4. Readily forms complexes of various types, e.g. $[\text{PdX}_4]^{2-}$. Undergoes oxidation to give PdO when heated in the air. Absorbs large volumes of hydrogen.

Occurrence: occurs in nature in the free state, in alloys with other platinum family metals (mostly with Pt), in chemical compounds.

Uses: in the chemical industry, in thermocouples and thermoregulators, in various electrical devices, in dentistry and jewelry. Palladium alloys with Pt and Rh are widely used in the organic synthesis as catalysts.

palmitic acid (hexadecanoic acid*, pelmitinic acid)

$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$. The most widely occurring fatty acid, a white solid. Found practically in all natural fats in the form of glycerides; it is the major component of the fat of hogs, coconut oil, etc. Manufactured by the saponification of fats. The sodium salt of palmitic acid dissolves in water and has a washing action; together with other metal salts, it is used in soap production.

paraffins (alkanes). See *saturated hydrocarbons*.

paraffin wax. A mixture of solid high-molecular-weight hydrocarbons of the methane series, colour white or yellowish, m.p. 50 to 70 °C, dissolves in gasoline. Stable to the action of acids, alkalis, oxidants, and halogens at room temperature. Prepared from petroleum. Used in the paper, textile industries, in polygraphy, in the manufacture of leather, matches, in medicine, electrical insulation, in candles. In experimental physics paraffin wax is employed as neutron moderator. In the chemical industry in the manufacture of the higher fatty acids and alcohols, soaps, etc.

paraformaldehyde (paraform, polyoxymethylene, polymerized formic aldehyde) $(-\text{H}_2\text{C}-\text{O}-)_n$. The product of the polymerization of formaldehyde with a molecular mass in the range of 40 000 to 120 000.

Properties: a white crystalline powder, m.p. about 180 °C, stable, retains rigidity and mechanical strength up to 120 °C, resistant to abrasion and action of organic solvents and oils.

Uses: as a material for gears, sliding bearings, parts of automobiles, electrotechnical devices; gives very strong films; can be used in fibre manufacture.

parathion $(C_2H_5O)_2=POC_6H_4NO_2$. An ester (diethyl mono-

$$\begin{array}{c} \parallel \\ S \end{array}$$

nitrophenylthiophosphate), an insecticide. A viscous oily liquid with a dark-brown colour and a disagreeable garlic odour. Slightly soluble in water, soluble in organic solvents, can be hydrolyzed by water, acids, and alkalis. Very poisonous. Used to kill insect pests.

Paris green. See *copper acetoarsenite*.

passivation of metals. A coating of metals with a protecting film (usually an oxide film) under the action of oxidants to render them corrosion resistance. Can be carried out electrochemically.

peat. A solid fuel; destructive distillation of peat gives peat coke that can be used in the manufacture of high quality pig iron and some other chemical products.

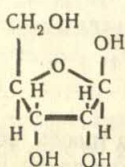
pegmatite [Gk *pegma*, framework; so called because of closeness of texture] (giant granite). A rock characterized by a varied and complex composition of mineral constituents and high percentages of volatile components such as water, fluorine compounds, and boron compounds. A source of feldspar (potassium feldspar is used in electric insulation, and sodium varieties in glass manufacture), mica (electrotechnical applications), precious stones (emerald, chrysoberyl, tourmaline, amethyst).

penicillin. An antibiotic obtained from some kinds of molds of the *Penicillium* family, suppresses the growth of many bacteria, used to treat inflammation of the lungs, quinsy, gangrene, etc. At present benzylpenicillin is mostly manufactured.

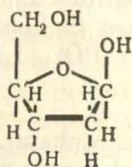
pentane, C_5H_{12} . Any of the three isomers of the composition indicated; a saturated hydrocarbon. Occurs in petroleum and petroleum gases, used as a solvent and as a component of liquid fuels.

pentose. A monosaccharide containing five carbon atoms in a molecule, e.g. ribose, xylose. The general formula is $C_5H_{10}O_5$. Pentoses are very common in nature, occur in the free state, or as constituents of glucosides and poly-

saccharides. Ribose and its derivative, deoxyribose



β - ribose



β - deoxyribose

are the structure components of nucleic acids.

pepsin [Gk *pepsis*, digestion]. An enzyme from gastric juice, splits proteins to peptides.

peptide. An organic substance containing two or more amino

acid residues linked by the peptide bond, $\begin{array}{c} \text{O} \quad \text{H} \\ || \quad | \\ -\text{C}-\text{N}- \end{array}$. Peptides are intermediates formed in the decomposition of proteins in plants and animals. They undergo splitting into free amino acids under the action of peptidase enzymes which cause the dissociation of the peptide bond. See also *polypeptides*.

peptide bond. See *protein*, *peptide*.

peptization. A separation of aggregates formed in the coagulation of a disperse system into primary particles under the action of liquid medium, e.g. water, or special reagents. One of the methods of the preparation of colloidal solutions, applied in industry in the manufacture of high-dispersity suspensions of clays and other substances.

peracid. An acid with a larger proportion of oxygen than found in other acids of the same element, e.g. perchloric acid, HClO_4 . The same prefix is sometimes used in naming acids containing $-\text{O}-\text{O}-$ groups, e.g. persulphuric acid, $\text{H}_2\text{S}_2\text{O}_8$. See *peroxyacids*.

perchlorate. A salt of perchloric acid, HClO_4 . Potassium perchlorate, KClO_4 , is used as an oxidizing agent, in the manufacture of explosives, etc.



perchloric acid HClO_4 , $\text{HO}-\text{Cl} \begin{array}{c} \nearrow \text{O} \\ \searrow \text{O} \end{array}$. The strongest mono-

basic acid when in aqueous solution, a very strong oxidizing agent in the free state. Explosive. Perchloric acid

and its salts are used as oxidizing agents. Potassium perchlorate, KClO_4 , is sparingly soluble in water, used in the manufacture of explosives; magnesium perchlorate, $\text{Mg}(\text{ClO}_4)_2$, is a drying agent.

perhydrol. A 30% aqueous solution of hydrogen peroxide, a strong oxidizing agent.

period. See *Periodic Table of Elements by D.I. Mendeleev.*

periodic acid HIO_4 . A weak acid, crystallizes with two water molecules, $\text{HIO}_4 \cdot 2\text{H}_2\text{O}$. Used in the analytical chemistry as an oxidizing agent. Its salts are called periodates.

periodic law by D. I. Mendeleev. See *Periodic Table of Elements by D.I. Mendeleev.*

Periodic Table of Elements by D.I. Mendeleev. A natural arrangement of the chemical elements. Mendeleev suggested that the elements should be ordered according to increasing atomic masses (weights) and grouped together according to their properties. The table thus constructed brought out the periodic law according to which "the physical and chemical properties of the elements as observed in the properties of simple and complex bodies composed of these elements are in periodic dependence upon their atomic weights" (1869-1871). The periodic law and the periodic table revealed interrelations between all the known elements and allowed to predict unknown ones and describe their properties. The discovery of the periodic law resulted in the rationalization of patterns of the properties of the chemical compounds of various elements, the discovery of new elements, and the synthesis of a lot of new substances. The periodic recurrence of elements with similar properties depends on the periodic changes in the structure of the electronic shells of atoms as the number of electrons, or the positive charge of the nucleus, Z , increases. The modern formulation of the periodic law is as follows: "The properties of the elements and their simple and complex compounds are a periodic function of the charge of their atomic nuclei, Z ". For that reason the elements are arranged according to their Z values which as a rule parallel the atomic weights except for few inversions, viz. Ar-K, Co-Ni, Te-I, Th-Pa, depending on the isotopic composition of the elements. The elements in the periodic table are divided into groups and periods (rows); each group is in its turn subdivided into subgroups A and B. The elements occurring

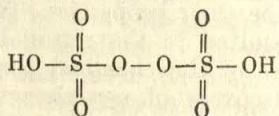
in the same subgroup have similar chemical properties. The A and B subgroup elements of the same group are also analogous to a degree, especially when they occur in the higher oxidation states (the higher oxidation state is as a rule equal to the number of the group). Each period except for the first one begins with an alkali metal and ends with an inert gas including all the elements in between; it contains a strictly definite number of elements. The Periodic Table of Elements includes 9 groups and 7 periods; at present the seventh period is incomplete.

permanganate. A salt of permanganic acid, HMnO_4 . Colour red-violet. Potassium permanganate, KMnO_4 , is used in chemistry (an oxidizing agent), in medicine (disinfectant).

permutite [L *permutare*, to change thoroughly]. Synthetic aluminium silicates of a composition similar to that of natural zeolites, ion exchangers, used for water softening. Permutite is a trademark for a line of cation and anion exchangers.

peroxide. A compound containing the peroxo group, $-\text{O}-\text{O}-$, e.g. hydrogen peroxide, H_2O_2 ; sodium peroxide, Na_2O_2 . Easily releases oxygen.

peroxyacids. Acids containing the peroxo chain, $-\text{O}-\text{O}-$, e.g. peroxydisulphuric acid (persulphuric acid), $\text{H}_2\text{S}_2\text{O}_8$:



Like peroxides all the peroxyacids are strong oxidizing agents. Salts of peroxyacids, e.g. peroxydisulphates (persulphates) have important practical applications. See also *peracids*.

peroxydisulphate (persulphate). A salt of peroxydisulphuric (persulphuric) acid, $\text{H}_2\text{S}_2\text{O}_8$. Persulphates are strong oxidizing agents. Ammonium persulphate, $(\text{NH}_4)_2\text{S}_2\text{O}_8$, is used to induce polymerization reactions, in photography. Potassium persulphate, $\text{K}_2\text{S}_2\text{O}_8$, is an intermediate in the synthesis of H_2O_2 , an oxidizing agent, used in bleaching fats, soap, can initiate polymerization processes, etc.

pesticide [L *pestis*, a plague + L *caedere*, to kill]. Any substance used to kill vermins or destroy bacteria to protect

crops and live-stock; pesticides also include rodenticides (poisons against rats, mice, etc.) and herbicides (weed-killers), and also chemicals used to destroy undesired bush and tree plants. Pesticides should be used very carefully because most of them can cause trouble to man, farming, and nature as well as to pests.

petrography [Gk *petra*, a rock, or *petros*, a stone]. The science dealing with rocks, their chemical and mineralogical composition, structure, conditions of formation, and occurrence.

petroleum. A fossil liquid fuel, a complex mixture of organic substances including saturated hydrocarbons (paraffins), naphthenes (cycloparaffins), aromatic hydrocarbons, etc. Petroleums from different localities have different prevalent constituents. As a rule petroleum also contains sulphur-, nitrogen-, and oxygen-containing substances. Petroleum is an oily liquid with a characteristic odour, dark, lighter than water where it is insoluble. There are several explanations of the origin of petroleum. Petroleum is the most important source of fuels, lubricants, and other products, and one of the most important raw materials for the chemical industry. Primary processing of petroleum is its distillation which gives ligroin, gasoline, kerosine, fuel oil, lubricating oil, paraffin wax, road oil, and asphalt. Secondary processing (cracking, pyrolysis) gives additional portions of liquid fuel, various hydrocarbons, mainly of the aromatic series (benzene, toluene, etc.). Gases accompanying petroleum and formed in the cracking of petroleum are important as fuels and as starting materials for the chemical industry.

petroleum chemistry. A branch of chemistry dealing with the chemical processing of petroleum and natural gases with the aim of using them as raw materials for the synthesis of various substances. For that purpose products obtained from primary processing of petroleum are subjected to dehydrogenation, hydrogenation, alkylation, halogenation, polymerization, condensation, cyclization, oxidation, nitration, sulphonation, and so on.

petroleum ether. A mixture of light hydrocarbons (pentanes and hexanes) obtained from petroleum gases and low-boiling petroleum fractions. A colourless liquid, b.p. 40 to 70 °C. Used as a solvent of fats, oils, resins, etc.

petroleum gas. A mixture of various gaseous hydrocarbons dissolved in petroleum, mainly propane and butanes, which are evolved during petroleum extraction and primary processing; also gases formed in cracking of petroleum and containing saturated and unsaturated (ethylene, acetylene) hydrocarbons. Petroleum gases are used as fuel and in the synthesis of various substances, e.g. propylene, butylenes, and butadiene for the manufacture of plastics and rubber.

petroleum jelly (Vaseline, petrolatum). A semi-solid mixture of hydrocarbons. Used for impregnating paper and fabrics, in electrotechnical devices, as a lubricating grease for bearings, in the manufacture of special lubricants, for coating metals to prevent corrosion, in medicine, and cosmetics.

pH. The quantity characterizing the concentration (activity) of hydrogen anions in solutions numerically equal to the logarithm of the reciprocal of the hydrogen ion concentration in moles per litre, $\text{pH} = \log (1/[\text{H}^+])$, where $[\text{H}^+]$ is the concentration; pH rather than $[\text{H}^+]$ values are used in calculations because the latter vary within too wide limits. Aqueous solutions are characterized by pH of 0 to 14. For pure water and neutral solutions, $\text{pH} = 7$, for acidic solutions $\text{pH} < 7$, and for basic $\text{pH} > 7$. pH values are determined with the help of acid-base indicators or by potentiometric measurements.

phase. A homogeneous part of a heterogeneous system, as ice and water at 0 °C making up a two-phase system where water is the liquid and ice the solid phase.

phase analysis. A branch of the analytical chemistry dealing with the determination of simple or complex compounds in a sample rather than its elementary composition.

phenol (carbolic acid, hydroxybenzene) $\text{C}_6\text{H}_5\text{OH}$.

Properties: colourless crystals with a characteristic odour, turn pink in the air. Poisonous. Shows weakly acidic properties, reacts with alkalis to give metal phenates (phenolates). The reaction with bromine gives tribromophenol.

Derivation: from coal-tar oil.

Uses: in the manufacture of phenol-formaldehyde resins, synthetic fibre, dyes, pesticides, pharmaceuticals (acetylsalicylic acid, salol). Dilute aqueous solutions of phenol are used as disinfectant. Tribromophenol (bromol) is

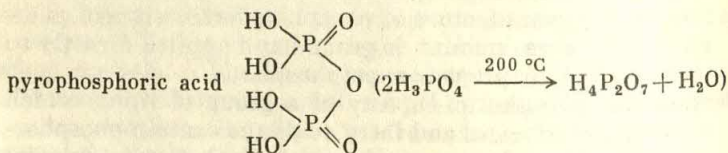
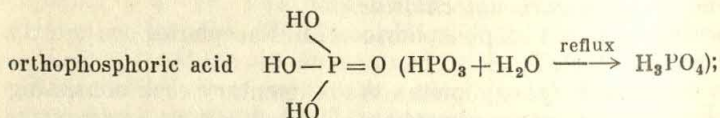
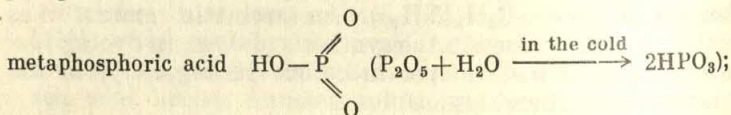
- employed as a starting material for the synthesis of bismuth tribromophenate, an antiseptic.
- phenol-formaldehyde plastics.** Made from phenol-formaldehyde resins, used in the manufacture of moulded and cast plastic articles, laminates, protective coatings.
- phenol-formaldehyde resins.** Synthetic resins obtained by the polycondensation of phenol with formaldehyde, good electric insulators, chemically stable and strong materials. Used in the manufacture of plastics, adhesives, lacquers.
- phenolphthalein.** An acid-base indicator, colourless in acid and red-violet in basic media: the change in colour occurs at pH of 8.2 to 10. Used in medicine as a laxative.
- phenols.** Aromatic compounds containing hydroxyl groups attached directly to the aromatic nucleus; classified as monohydric, dihydric, etc. phenols depending on the number of hydroxyl functions. See *phenol*, *pyrocatechol*, *resorcinol*, *hydroquinone*, and *pyrogalllic acid*.
- phenylenediamine** $C_6H_4(NH_2)_2$. An aromatic amine, has three isomers. Used in the synthesis of dyes, in dyeing furs and hair, as a developer in colour photography, in the analytical chemistry.
- phosgene.** See *carbonyl chloride*.
- phosphate.** A salt of phosphoric acid. Phosphates are mostly used as fertilizers.
- phosphate rock (phosphorite).** A sedimentary rock consisting largely of calcium phosphate. Used chiefly as a raw material for the manufacture of phosphate fertilizers and phosphorus. A large amount is ground and applied directly to soil or used to prepare superphosphate.
- phosphatide (phospholipid).** Any of a group of lipids which are esters of glycerol and fatty acids and contain phosphoric acid and a nitrogenous base (choline) as constituents; found in brain, liver, muscles, tissue (especially nervous) in man and animals; participate in redox processes in organisms; important for immunity, growth processes, permeability of cells.
- phosphine (hydrogen phosphide)** PH_3 . A gas, forms phosphonium salts in solution, e.g. PH_4I . Exceedingly poisonous.
- phosphines.** Organic derivatives of phosphine, similar to amines, e.g. $(CH_3)_3P$, $(C_6H_5)_3P$.
- phosphite.** A salt of phosphorous acid, H_3PO_3 ; also its ester.
- phosphoprotein.** A complex compound composed of a protein

and phosphoric acid. Phosphoproteins are essential to growing organisms, for they supply a number of amino acids necessary for growth.

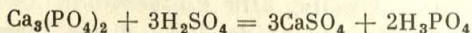
phosphor. A substance that can convert absorbed energy into radiation, exhibits luminescence. Most inorganic substances of this kind are phosphor crystals. Their luminescence depends on the presence of small amounts (up to 0.001%) of cation impurities, e.g. traces of copper activate fluorescence of zinc sulphide. Inorganic phosphors are used in luminescent lamps, electron-beam tubes, screens for roentgenoscopy, as indicators of radiation. Organic phosphors are employed to prepare bright phosphorescent pigments, luminescent materials; in chemistry, biology, medicine, criminology as analytical detectors of high sensitivity.

phosphorescence. A luminescence. Unlike fluorescence, persists after excitation is removed.

phosphoric acids:



Orthophosphoric or merely phosphoric acid is applied more widely than the meta- and pyro-forms; it is made from calcium phosphate rocks in industry:



It is used in the manufacture of fertilizers, in the food and textile industries, and in medicine. Its salts, orthophosphates or phosphates, also have important practical applications (fertilizers, components of enamels, glasses). See *phosphorus*.

phosphorous acid H_3PO_3 . A weak dibasic acid; its salts (phosphites) are used as reducing agents in inorganic syntheses.

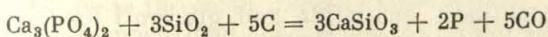
phosphorous acid, hypo- H_2PO_2 . See *hypophosphorous acid*.

phosphorus [Gk *phosphoros*, bringer of light] P. A Group V element of the 3rd period of the Mendeleev Periodic Table of Elements, atomic number 15, atomic mass 30.9738, one stable isotope, ^{31}P . Discovered (1669) by alchemist Brand. Essential to animal and plant life (see *phosphatide*, *phosphoprotein*, *nucleotide*, *adenosine triphosphate*).

Properties: a non-metallic element existing in several allotropic forms (red, white). The most reactive form is white phosphorus; it ignites spontaneously in the air and for that reason is stored under water, poisonous, exhibits phosphorescence (hence the name of the element). Phosphorus combines directly with oxygen, halogens, sulphur, and metals. The oxidation states in compounds +5 (P_2O_5), +3 (P_2O_3), and -3 (PH_3).

Occurrence: see *phosphate rock*, *apatite*.

Derivation: by reducing phosphate minerals with coke:



Uses: in pyrotechnics, in the manufacture of matches, as a deoxidizer in metallurgy, as an alloying element. Certain phosphides are semiconductors (GaP, InP, etc.). Phosphoric anhydride is employed as a drying agent. The most important compounds of phosphorus are phosphoric acid derivatives and phosphorus-containing fertilizers.

Organophosphorus derivatives are widely applied as insecticides.

phosphorus fertilizers. Mineral fertilizers containing phosphorus, e.g: superphosphate, ammophos, potassium ortho- and meta-phosphates, precipitated calcium phosphate, Thomas slag, etc. Made from phosphate rock, apatite.

photochemical reaction. A reaction induced by light, as photosynthesis in plants, decomposition of silver bromide in the light-sensitive layer of photoplates, conversion of oxygen to ozone in the higher layer of the atmosphere, reaction of chlorine with hydrogen to produce HCl in the light.

photochemistry. A branch of chemistry studying photochemical reactions.

photocolorimetry. Quantitative determination of the concentration of a substance by measuring absorption of

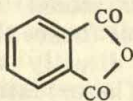
light in the visible and near ultraviolet regions with the help of photoelectric colorimeters.

photoluminescence. Luminescence induced by visible or ultraviolet light, see *luminescence*.

photometric methods of analysis. A group of analytical procedures based on measurement of absorption or scattering of light or fluorescence induced by UV radiation, viz. spectrophotometry, photolorimetry, colorimetry, turbidimetry, fluorimetry.

phthalic acid. The simplest dibasic aromatic acid.

Properties: a crystalline solid, loses water above 200 °C to give phthalic anhydride:



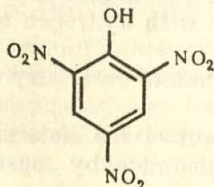
Derivation: by the oxidation of naphthalene.

Uses: phthalic anhydride is used in the synthesis of dyes, phenolphthalein, the manufacture of alkyd resins (from phthalic anhydride and glycerol) for the preparation of lacquers and adhesives with insulating properties. Esters of phthalic acid are used as plasticizers, insect repellents (dimethyl phthalate).

physical chemistry. The most important branch of the chemical science using the achievements and methods of physics for the study, explanation, and discovery of the patterns of chemical phenomena. Physical chemistry includes the theory of the structure of chemical compounds, chemical thermodynamics and chemical kinetics, electrochemistry and chemistry of colloids, the theory of catalysis, solutions, photochemistry, and radiation chemistry. None of the other branches of chemistry (organic, inorganic, and analytical chemistry) can advance without recourse to physical chemistry.

pi-bond. See *sigma-* and *pi-bonds*.

picric acid (trinitrophenol)



Properties: a yellow crystalline substance.

Uses: picric acid and its salts, picrates, are used as explosives, in the analytical chemistry for the determination of potassium and sodium.

pig iron. Not malleable iron containing carbon (usually more than 2% carbon) and admixtures of Si, Mn, P, and S (unalloyed pig iron). Alloyed pig iron also contains alloying elements (Cr, Ni, Mo, Cu, Al, more than 2% Mn, and more than 4% Si). Widely used in mechanical engineering.

pitch. A residue after the distillation of coal, peat, or wood tar-oil and petroleum tailings, a solid or semi-solid tenacious substance of black colour. Used in the manufacture of waterproof materials, pitch coke, for paving, roofing, etc.

plasma [Gk *plassein*, to form, mould]. The fourth state of matter, fully or partly ionized gas composed of approximately equal numbers of positively and negatively charged particles. Most of the universe is in the plasma state (stars, stellar atmospheres, nebulae, interstellar medium). Near the earth plasma exists as solar wind, in the magnetosphere and ionosphere. In laboratories and industry plasma is produced by electric discharges. Flames and explosions also generate plasma.

plastic. A material made from natural or synthetic high-molecular-weight compounds, used in the manufacture of various products for industrial and household applications. Apart from polymers, plastics contain fillers, plasticizers, and dyes.

plastic, gas-filled. A very light plastic, can be made of various synthetic polymer materials. Has a foam-like structure. Soundproof, a good thermal and electrical insulator. The chemical and mechanical properties and heat-resistance of such plastics depend to a considerable degree on the initial polymer, and their insulating properties on their physical structure. Can be obtained from all the polymers known at present. Classified as foam plastics (plastics with closed-cell structure) and plastics with open porous structures where all pores are connected with each other and with the atmosphere. Used in aircraft, in building, in the manufacture of furniture, etc.

plasticine [Gk *plassien*, to form]. A material for modelling, made of clay with admixtures of wax, fat, and other materials preventing drying.

plasticizer. A non-volatile organic solvent forming gels with materials to which it is added. Used to decrease the temperature of softening (vitrification) of polymer materials, increase their elasticity and resistance to frost. The main applications are the manufacture of plastics, rubbers, synthetic leather, lacquers, and dyes. The most familiar plasticizers are esters of phthalic acid, esters of phosphoric acid, various oils.

platinum [Sp *plata*, silver] Pt. A Group VIII element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 78, atomic mass 195.09. The most abundant of the platinum family metals.

Properties: a silvery white metal, ductile, malleable. At room temperature reacts only with *aqua regia* and bromine. The usual oxidation states in compounds are +2, +4. Has many valuable properties such as chemical stability, high melting point, the constancy of mass at low and high temperatures, the ability to accelerate chemical reactions. Forms many complex compounds.

Occurrence: mainly found in the free state.

Uses: in the manufacture of chemical equipment for work in aggressive media, as a catalyst, in electrical devices, in jewelry. Platinum electrodes are employed in various fields of the chemical industry. Used in the pure form and as alloy component.

platinum black. Finely divided metallic platinum prepared by reducing platinum compounds. Used as catalyst in chemical processes.

platinum metals. Here belong ruthenium (Ru), rhodium (Rh), palladium (Pd) (the lighter platinum metals) and osmium (Os), iridium (Ir), and platinum (Pt) (the heavier platinum metals). Occur in nature together with platinum. All platinum metals are stable towards chemical actions.

Plexiglas. Trademark for cast acrylic resin (methyl methacrylate) thermoplastic sheets and moulding powders, workable, used in aircraft, in the manufacture of various transparent sections for industrial and household applications.

plutonium [after planet Pluto next to Neptune; see *neptunium*] Pu. A radioactive element of the actinide series, atomic number 94, atomic mass of the longest lived isotope 242. Synthesized in the USA in 1940. Plutonium-239 ($T_{1/2} = 24\,400$ years) is of major importance since it is

fissionable with slow neutrons and used in nuclear energy devices.

Properties: a white glittering metal; the chemistry of plutonium is fairly complex, it exists in compounds in the oxidation states of +2 to +7; the most stable compounds contain Pu^{4+} . Emits alpha rays, dangerous to living organisms.

Pobedit. A metalloceramic alloy with tungsten carbide, WC, as the major component, very hard. Used in metal working.

poison gas. Any toxic substance (a gas, a liquid, or a solid) used in chemical warfare. First employed in World War I.

polar bond. A chemical bond with a permanent dipole arising from non-coincidence of the negative and positive charge centres. Most covalent and donor-acceptor bonds are polar. Molecules with polar bonds are as a rule more reactive than those with non-polar ones. A distinction should be drawn between polar bonds and polar molecules; for polarity of molecules also depends on the geometrical arrangement of atoms.

polar molecule. See *dipole*.

polarization. A shift of the electronic shells and nuclei of atoms or ions with respect to each other under the action of external electric field. Increases dipole moments. The polarization of chemical bonds is the shift of electrons involved in a covalent bonding to the more electronegative atom. As a result of this the bond becomes more polar or even ionic.

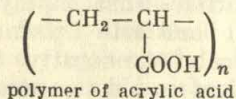
polarography. One of the most important electrochemical methods of analysis, suggested by Geirovskii in 1922. The concentration of a substance is found from the limiting current value to which it is proportional; the limiting current value is determined from the current vs. voltage dependences called polarograms; polarograms are taken with cathodes having far smaller surface areas than anodes. The method is used in the determination of a number of ions (e.g. cadmium, zinc, lead) and some organic substances.

polonium (after Poland, the native land of Marie Curie) Po. A Group VI radioactive element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 84, discovered in pitchblende by Pierre and Marie Curie in 1898. The longest-lived natural isotope, ^{210}Po ($T_{1/2}$ 138 days), undergoes alpha-decay.

Properties: a soft silvery white metal, the oxidation states in compounds -2 , $+2$, $+4$, $+6$; resembles tellurium and bismuth in its chemical properties.

Uses: in neutron sources, in radiochemistry to study chemical transformations under alpha-irradiation, in the manufacture of atomic batteries.

polyacrylate. Any polymeric material made by polymerizing acrylic acid or its derivatives (esters, nitrile, amide) or copolymerizing acrylic acid derivatives with each other or with other unsaturated hydrocarbons:



Polyacrylates are colourless, transparent, stable to the action of light; approximate quartz in their ability to transmit ultraviolet radiation. Polymers of esters of acrylic and especially methacrylic acids and polymers and copolymers of acrylonitrile are the most important materials of the series. Polyacrylates are unattacked by dilute alkalis and acids. Used in the manufacture of films, lacquers, and adhesives. See also *Plexiglas*.

polyacrylonitrile $\left(\begin{array}{c} -\text{CH}_2-\text{CH}- \\ | \\ \text{CN} \end{array} \right)_n$ is widely used in the

manufacture of strong heat-resistant fibres and as copolymer with butadiene (acrylonitrile rubber).

polyamide. Any synthetic polymer containing the amide groups, $-\text{CONH}-$, in the main chain.

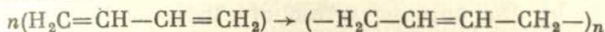
Derivation: by the polycondensation: from amides of polybasic acids and aldehydes; from the higher amino acids or diamines and dicarboxylic acids; from caprolactam and salts of diamines of dicarboxylic acids, etc.

Uses: nylon fibre, films, adhesives, and coatings; protection of metals and concrete from corrosion; medicine (surgical sutures, eye surgery, artificial blood vessels, bone substitutes); artificial leather.

polyarylate. A complex polyester obtained by the condensation of a dihydric phenol and a dicarboxylic acid. Polyarylates are used in the manufacture of insulators, foam plastics, films, and various heat-resistant goods.

polybutadiene. A polyhydrocarbon obtained by polymerizing

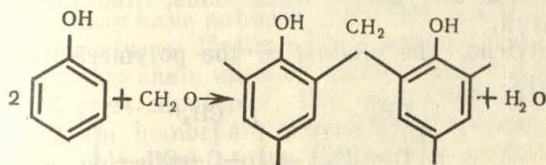
butadiene:



An elastic rubber-like substance, gastight, stable to the action of water. The first synthetic rubber. The ability of butadiene to undergo polymerization was discovered by Lebedev (1909). The polymerization can be induced by various substances, e.g. by sodium metal, which was used in the first industrial process for the manufacture of synthetic rubber in the USSR (1932).

polycarbonate. A thermoplastic polymer material made of polyesters of carbonic acid and dihydroxy compounds of the paraffin and aromatic series.

polycondensation. A method for the synthesis of high-molecular-weight compounds based on the substitution or exchange reactions between the functional groups of the starting materials (monomers). An example is the reaction between formaldehyde and phenol:

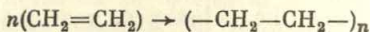


Unlike polymerization, gives products of a different composition from the initial compounds because of the formation of certain other than polymer substances (H₂O, HCl, NH₃, etc.).

polyelectrolyte. A polymer containing groups capable of ionization in aqueous solutions, e.g. the most important biological polymers, proteins, and nucleic acids. Polyelectrolytes that can act as ion exchangers have important practical applications.

polyester. A high-molecular-weight compound prepared by the polycondensation of a polybasic acid or its aldehyde with a polyhydric alcohol. Amber is an example of a natural polyester. Of synthetic polyesters, Glyptal resins, polyethylene terephthalate, polyesters of maleic acid, and polyesters of acrylic acid have found practical applications. The term polyester resin is applied more specifically to unsaturated esters, e.g. esters of maleic acid, while saturated esters such as Glyptal resins are classified as alkyd resins.

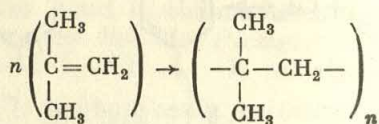
polyethylene. One of the most important polymer materials. Made by the polymerization of ethylene:



The product is liquid and used as a lubricant if each polyethylene molecule contains 50 to 70 monomer units, a white solid if the number of monomer units is 100 to 120, and a solid, semitransparent, elastic, strong material with specific gravity of 0.92 if that number is thousand or more. The term polyethylene is usually referred to the high-molecular-weight product. Polyethylene is resistant to frost, flexible when warm, has a high tensile strength. Gives bluish pale fire when burns, is unattacked by alkalis, acids, and oxidizing agents under ordinary conditions.

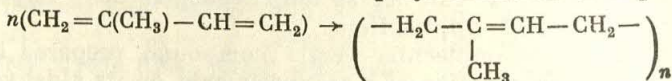
Uses: electric insulation, the manufacture of water pipes, goods for householding, vessels for storing and transporting alkalis and concentrated acids, films for packaging food-stuff.

polyisobutylene. The product of the polymerization of isobutylene:



Has intermediate properties between plastics and rubbers: it shows high chemical stability and heat resistance, is gastight and unattacked by moisture, however, being far less elastic than rubbers. Used for protection from corrosion and in the manufacture of electric insulators.

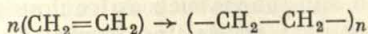
polyisoprene. The product of the polymerization of isoprene,



Has properties similar to natural rubber and superior to those of butadiene rubber, used in the manufacture of tires.

polymer [Gk *poly*, many + *meros*, a part]. A product of combination (polymerization) of many monomers (identical molecules) into one macromolecule. Polymerization results in a substantial change of the properties of the material, while the elementary composition remains unal-

tered. The number of initial (monomer) molecules constituting a polymer molecule may be from two to many thousands and even millions; depending on that number polymerization products are called high or low polymers. The recurring group of atoms in a polymer which usually forms the skeleton of a monomer molecule is called a polymer chain unit:



The number of units in a chain is called the degree of polymerization (n). The product of n by the molecular mass of one chain unit gives the mass of a macromolecule, M . High polymers have $M=10^4$ to 10^6 ; polymers with low M values are called oligomers. Polymers built of identical units are called homopolymers, and those containing dissimilar units copolymers. Copolymers (linear) whose main chain incorporates segments composed of identical monomer units are called block copolymers. Polymers may have not only linear but also branched and spatial structures. If the main chain includes identical units and side chain units of another type, the compound is called graft copolymer. The main chain may contain identical (in homochain polymers) or different (in heterochain polymers) atoms. Carbochain polymers whose main chain only contains carbon atoms are the most familiar ones. Species with carbon-oxygen, carbon-nitrogen, and carbon-sulphur chains also occur rather frequently. Inorganic polymers contain no carbon atoms in the main chain. Examples of naturally occurring polymers are proteins, nucleic acids, cellulose, starch, and natural rubber. Synthetic polymers include polyethylene, polypropylene, phenol-formaldehyde resins, etc. Most high polymers are solids, many of them are plastic and elastic materials. Polymers are widely used in the manufacture of various structural materials, fibres, rubbers, plastics, coatings, etc. Plastics are used in electrical devices instead of nonferrous metals, in the manufacture of apparatus for the chemical and petroleum industries, in building, agriculture, in the production of food-stuff, in medicine, etc.

polymerization. The reaction of joining similar molecules into complex molecules of large molecular weights: $nM \rightarrow M_n$, where M is a monomer molecule, M_n a macro-

molecule composed of monomer units, and n the degree of polymerization. The product of polymerization has the same elementary composition as the initial substance (monomer) because the reaction does not give any side products.

polymethacrylate. See *polyacrylate*.

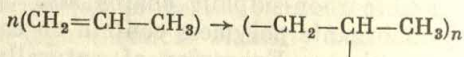
polymorphism [Gk *poly*, many + *morphe*, a form]. The property of some substances such as iron, sulphur, or quartz to occur in several crystalline forms. The transition of one form into another is called a polymorphic transformation. Polymorphism of minerals is a frequently occurring phenomenon. Polymorphism of simple substances is *allotropy*.

polyolefin. A product of polymerization of an unsaturated hydrocarbon of the ethylene series. Polyolefins of practical importance are polyethylene, polyisobutylene, and copolymers of ethylene, propylene, and isobutylene.

polyoxymethylene. See *paraformaldehyde*.

polypeptide. A peptide containing a large number, 6 to 90, of amino acid residues. Splitting of proteins under the action of enzymes and synthesis of proteins from amino acids yield polypeptides in organisms.

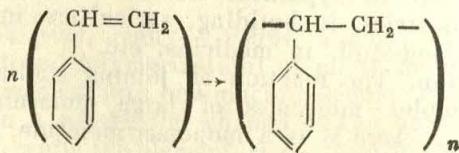
polypropylene. A rigid and thermoplastic material with good mechanical properties and softening temperature of 150 to 160 °C, the product of the polymerization of propylene in the presence of catalysts containing metals:



The chief uses are: electrical insulation, package films, chemically stable pipes, parts of equipment, strong fibre.

polysaccharide. A complex carbohydrate whose molecules contain a large number of monosaccharide residues, e.g. cellulose, starch.

polystyrene. The product of the polymerization of styrene (vinylbenzene):

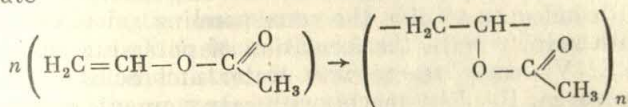


An elastic colourless solid used in the manufacture of plastics which are widely applied in electrical engineering, in household (various containers, toys, statuettes, etc.), in the manufacture of lenses, coloured tiles for building, etc.

polysulphide. Any compound of the general formula M_2S_n , e.g. ammonium polysulphide, $(NH_4)_2S_n$. Decomposes under the action of acids with evolution of H_2S and precipitation of sulphur. Polysulphides are used in the analytical chemistry to separate ion mixtures, in the manufacture of some rubbers, etc.

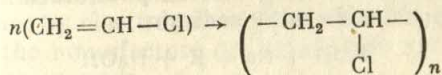
polytetrafluoroethylene. See *Teflon*.

polyvinyl acetate. The product of the polymerization of vinyl acetate



Used in the manufacture of plastics, lacquers, dyes, adhesives, etc. Stable in the light, swells in water. Solutions of acids and alkalis hydrolyze it to polyvinyl alcohol, $(-CH_2-CH(OH)-)_n$.

polyvinyl chloride. The product of the polymerization of vinyl chloride:



A white amorphous powder. Plastics made of polyvinyl chloride are used in the manufacture of electric insulators, various household goods, waterproof coats, oilcloth for medical purposes, details of electric devices, chemically stable pipes, substitutes for type metal and leather.

porcelain. A ceramic material, dense, sintered, gastight and waterproof, white. Thin layers of porcelain are transparent. Made by sintering a mixture of kaolin, quartz, and feldspar. Special kinds of porcelain contain admixtures of zircon, talc, alumina, etc. Porcelain is stable towards all acids except hydrofluoric acid. Used in the manufacture of acidproof ceramics for the chemical industry and metallurgy, electric insulators, dishes, works of art.

porphyrin. Any of natural pigments containing nitrogen and found in non-protein parts of hemoglobin, chlorophyll, and some enzymes.

Portland cement. The most familiar kind of cement, named after the Isle of Portland, England. The major component is calcium silicate (see *cement*).

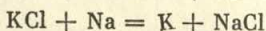
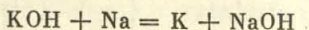
potash (D *pot*, a pot + *asch*, ash: so called from the original method of manufacture). A technical term for potassium carbonate, K_2CO_3 .

potassium [see *potash*] K. A Group I element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 19, atomic mass 39.102. Was first obtained by Davy in 1807 by electrolysis of KOH.

Properties: a silvery white very soft metal, easy to cut by a knife. The oxidation state in compounds +1. Very reactive, is rapidly oxidized in the air, reacts vigorously with halogens to give the corresponding salts. Combines with sulphur with the formation of potassium sulphide, K_2S . Violently reacts with water and acids replacing hydrogen. Readily reacts with many organic substances such as alcohol (forms potassium alkoxides), acetylene (in the cold to give KHC_2).

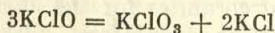
Occurrence: found in many rocks; the most important ones are feldspar and mica. Contained in sea water. The main minerals are sylvite, KCl , carnallite, $KCl \cdot MgCl_2 \cdot 6H_2O$, and kainite, $KCl \cdot MgSO_4 \cdot 3H_2O$.

Derivation: by reducing molten potassium hydroxide or potassium chloride with sodium:

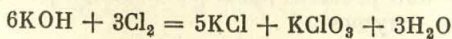


Uses: potassium metal is used in the manufacture of potassium peroxide, K_2O_2 , for oxygen-generating gas masks (releases oxygen under the action of moist air); as catalyst in the manufacture of some kinds of rubber. Potassium-sodium alloy is used as coolant in nuclear devices and as a reducing agent in the manufacture of certain metals, e.g. titanium. Potassium salts (KCl , etc.) are soil fertilizers. See also *potassium compounds*.

potassium chlorate (Berthollett's salt) $KClO_3$. Potassium salt of chloric acid. Prepared by heating potassium hypochlorite:



or by bubbling chlorine through a hot solution of potassium hydroxide:



An oxidizing agent. Used in the manufacture of matches, in pyrotechnics, as source of oxygen in laboratories.

potassium compounds. Potassium carbonate (potash), K_2CO_3 , used in the manufacture of glass and soap, as fertilizer, in the manufacture of potassium salts. Potassium nitrate (nitre, saltpetre), KNO_3 , a fertilizer, also used in pyrotechnics, as food preservative, in the manufacture of glass, etc. Potassium permanganate, $KMnO_4$, a strong oxidizing agent, used in the organic synthesis, in medicine, in the analytical chemistry. Potassium sulphate, K_2SO_4 , forms numerous double salts, e.g. alum, is used as fertilizer, and in the manufacture of alum and other potassium salts. Potassium chloride, KCl , used as fertilizer and in the manufacture of KOH and various potassium salts. Potassium chromate, K_2CrO_4 , used in the analytical chemistry. Potassium dichromate, $K_2Cr_2O_7$, used in the manufacture of matches, in pyrotechnics, photography, and in the analytical chemistry. Potassium cyanide, KCN , exceedingly poisonous, used in galvanoprocesses, for nitriding steel, for extraction of gold and silver from their ores.

potassium hydroxide (caustic potash) KOH .

Properties: colourless deliquescent crystals; a strong alkali in aqueous solutions.

Derivation: by electrolysis of potassium chloride solutions.

Uses: in the manufacture of liquid soaps and various potassium compounds.

potassium sodium tartrate (Rochelle salt, seignette salt). A double salt of tartaric acid, $NaKC_4H_4O_6 \cdot 4H_2O$, the first material to reveal peculiar electric properties, spontaneous polarization in a certain temperature range; the phenomenon was later called ferroelectricity.

potentiometry. A method for the study of various physico-chemical properties by measuring electromotive forces of reversible galvanic cells, widely used in the analytical chemistry in the determination of pH, concentrations of substances in solutions (potentiometric titration).

praseodymium [Gk *prasios*, green + *didymos*, twin) Pr. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 59, atomic mass 140.907, belongs with lanthanides. Discovered by von Welshbach in 1885.

Properties: the oxidation states in compounds +3, +4.

Uses: the manufacture of glass and porcelain, special kinds of steel, heat-resistant magnesium alloys.

precipitate. A substance that is separated out from solutions as a result of precipitation reactions in the amorphous or crystalline forms. See also *precipitation*.

precipitated calcium phosphate (calcium phosphate, tribasic).

A phosphorus-containing fertilizer, manufactured by reacting hydrated lime or chalk with phosphoric acid. Widely applied in agriculture.

precipitation. The isolation of one or several ions or substances in the form of insoluble or slightly soluble compounds, used to separate elements in the analytical chemistry and chemical industry. Various techniques of detection, separation, gravimetric and titrimetric determination of ions and substances are based on precipitation.

procaine, procaine hydrochloride. Colourless and odourless crystals soluble in water and ethanol. Used to produce local anaesthesia.

promotor. See *activator*.

propane $\text{CH}_3\text{—CH}_2\text{—CH}_3$. A saturated hydrocarbon of the methane series; gaseous fuel, found in natural and petroleum gases, used as fuel for internal combustion engines, in the manufacture of carbon black. Mixtures of propane and butane are kept in cylinders under pressure and used as fuel for household.

propylene (propene*) $\text{CH}_2\text{=CH—CH}_3$. An unsaturated hydrocarbon of the ethylene series, inflammable. Contained in gases resulting from cracking of petroleum, used in large amounts in the manufacture of glycerol, acrolein, acrylonitrile, acrylic alcohol, isopropyl alcohol, acetone, phenol, polypropylene, etc.

protactinium [Gk *protos*, first + actinium] Pa. A radioactive Group III element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 91, an actinide, discovered by Hahn and Meitner (1918) (Fajans and Göring are said to be co-discoverers). Occurs in nature as ^{231}Pa ($T_{1/2} = 34\,300$ years), precedes actinium in the actinium radioactive series, $^{231}\text{Pa} \rightarrow ^{227}\text{Ac}$, whence derives its name.

Properties: white-grey metal; the oxidation states +2, +3, +4, +5. Protactinium compounds are readily hydrolyzed and adsorbed from solutions on vessel walls.

protective coatings. Coatings produced on metals, alloys, etc. to protect them from corrosion, oxidation, and adsorption of gases. The usual techniques are anodizing, nickel plating, oxide coating, chrome plating, brass plating, copper plating, and the application of lacquers and dyes.

proteid. A complex protein, a compound of a protein with some other substance (carbohydrate, nucleic acid, etc.).

protein [Gk *proteios*, prime, chief]. A simple protein, that is a substance incorporating only amino acids.

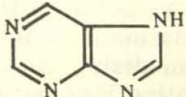
protium. A stable hydrogen isotope with the mass number 1; its nucleus is the proton.

proton [Gk *protos*, first]. A stable elementary particle with a unit positive electric charge, 1863 times heavier than an electron. Protons together with neutrons constitute all atomic nuclei; their number determines the nuclear charge value, Z , and the position of the corresponding element in the Mendeleev Periodic Table of Elements. The lightest nucleus is that of protium, ^1H , which contains one proton. As the hydrogen atom possesses a single electron, its ionization results in the formation of the positive H^+ ion which is hydrated in aqueous solutions, H_3O^+ . This ion plays an important role in acid-base equilibria (acid \rightleftharpoons \rightleftharpoons proton + base), ionic exchange, electrolytic dissociation, etc.

protonization. The addition of a proton, H^+ .

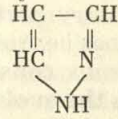
pure substance. An element or a compound, a solution, a mixture, etc. containing admixtures in the amount below a certain level: that level depends on the properties, method of synthesis, and intended use of the substance; usually, it is fractions of a per cent or less. Modern requirements to purity are very high (see *trace*).

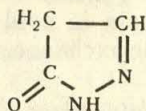
pumice stone [L *pumex*, pumice]. A porous variety of vitreous igneous rock, colour from white and bluish to yellow, brown, and black (depending on the percentage and valence of iron). Soundproof, a good thermal insulator, very permeable to gases. Fireproof. Chemically inert. Used as an abrasive, in the manufacture of filters for the chemical industry, employed as inert support for various catalysts. Other uses: building, manufacture of glass, household, etc.

purine  . An organic nitrogenous base. Purine


derivatives are very common in nature and play important parts in various biological processes. Purine nucleus occurs in many alkaloids, vitamins, antibiotics, and nucleotides.

putrefaction. The decomposition of organic nitrogen-containing substances (proteins) under the action of bacteria to simple mineral substances such as NH_3 , CO_2 , and H_2S , which are used by living organisms as starting materials for the synthesis of organic compounds.

pyrazole  . A five-membered heterocyclic compound incorporating two nitrogen atoms; resembles aromatic hydrocarbons in its chemical properties (easy to nitrate and sulphonate); a base. Pyrazole derivatives, especially pyrazolone,



are used in the manufacture of dyes and pharmaceuticals: pyrazolone dyes are used in colour photography; antipyrine, novaminsulphon, and aminophenazone in medicine. Pyrazolone derivatives are also used in the analytical chemistry for the separation and determination of a number of elements.

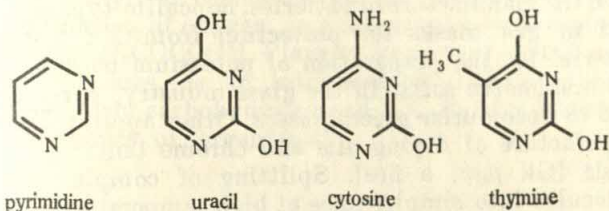
pyridine  N. A six-membered heterocyclic compound containing one nitrogen atom.

Properties: a colourless liquid with a sharp disagreeable odour; miscible with water and organic solvents. A weak base, forms salts with strong mineral acids, readily forms double salts and complex compounds.

Derivation: from coal-tar oil.

Uses: the synthesis of dyes, pharmaceuticals, insecticides, in the analytical chemistry, as a solvent of many organic and some inorganic substances, for denaturation of alcohol. Toxic, affects the nervous system and skin.

pyrimidine base. Any of a group of natural pyrimidine derivatives:

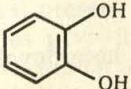


Differ from each other in the nature and arrangement of substituents in the pyrimidine nucleus. Pyrimidine bases are found in animal and plant tissue and in bacteria. The bases most important for biological processes are uracil, cytosine, and thymine, which occur in nucleic acids, nucleosides, and nucleotides.

pyrite (iron pyrites, fool's gold). A mineral, FeS_2 . Colour yellowish, metallic glitter, a semiconductor. Used in the chemical industry in the manufacture of sulphuric acid, sulphur, and iron vitriol.

pyrites. A group of minerals containing sulphur, iron, and also copper, arsenic, and admixtures. The most important ones are pyrite, FeS_2 , used in the manufacture of sulphur and sulphuric acid; arsenical pyrites, FeAsS , used in the manufacture of arsenic; copper pyrites or chalcopyrite, CuFeS_2 , etc.

pyrites, cinder. The residue from the burning of pyrite, composed mainly of iron oxide. Recovered for iron or copper and silver.

pyrocatechol  . A dihydric phenol, a reducing

agent. Used as a photographic developer, in the manufacture of dyes and pharmaceuticals (e.g. adrenaline).

pyrochemical analysis [Gk *pyr*, a fire]. A group of techniques for the determination of some chemical elements from

colouration of flame, borax beads, or phosphoric acid salts. Used, e.g. in the analysis of minerals.

pyrolusite. A mineral, MnO_2 .

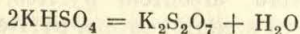
Properties: non-transparent, black or steel-grey colour. Shows semiconducting and piezoelectric properties. Dissolves in hydrochloric acid with evolution of chlorine. Uses: the manufacture of batteries, hopcalite-type catalysts used in gas masks for protection from CO; a starting material for the preparation of potassium permanganate and manganese salts. In the glass industry, pyrolusite is used to decolourize green glasses. Other applications: the manufacture of drying oils and chrome tanning.

pyrolysis [Gk *pyr*, a fire]. Splitting of complex organic molecules into simpler ones at high temperatures. Pyrolysis includes thermal destruction (decomposition), but it also may include condensation, isomerization and like processes. The term is usually referred to cracking of petroleum at about 700°C in the absence of air and often in the presence of catalysts; pyrolysis also occurs in destructive distillation of wood, peat, and bituminous coal (coking).

pyrometer. An instrument for measuring temperatures above 600°C .

pyrophosphate. A salt of pyrophosphoric acid, $\text{H}_4\text{P}_2\text{O}_7$. See *phosphoric acids*.

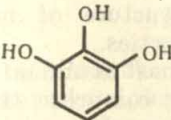
pyrosulphate. A salt of pyrosulphuric acid, $\text{H}_2\text{S}_2\text{O}_7$, synthesized by heating a hydrosulphate:



pyroxylin (soluble guncotton). A nitrocellulose consisting chiefly of cellulose tetranitrate, $\text{C}_{12}\text{H}_{16}\text{O}_6(\text{NO}_3)_{4n}$. An explosive, used in the manufacture of smokeless gunpowder.

pyrrole $\begin{array}{c} \text{HC} - \text{CH} \\ \parallel \quad \parallel \\ \text{HC} \quad \text{CH} \\ \diagdown \quad \diagup \\ \text{NH} \end{array}$. A five-membered heterocyclic compound,

a weak base. Found in bone oil obtained by destructive distillation of bones and in coal-tar oil. Pyrrole rings are incorporated in chlorophyll and haemoglobin molecules.

pyrogalllic acid  . A trihydric phenol, readily

undergoes oxidation. Used in the manufacture of dyes, in the analytical chemistry, in the gas analysis for the determination of oxygen, in photography (a developer).

pyruvic acid $\text{CH}_3\text{COCO}_2\text{H}$. Plays an important part in metabolism processes, is an intermediate in the synthesis of proteins from carbohydrates and v.v. in vivo. Contained in all tissues of organisms.

Q

qualitative analysis. A combination of chemical, physicochemical, and physical methods of the identification of elements, radicals, and compounds contained in a given sample; uses characteristic chemical reactions which are easy to carry out and which are accompanied by colour changes, precipitation or dissolution, evolution of gases, etc. The more selective and sensitive the reactions the better. Qualitative analysis of aqueous solutions is based on ionic reactions and serves to detect cations and anions.

quantitative analysis. A group of techniques for determining the amount of elements (ions), radicals, functional groups, compounds, or phases contained in a given sample. Used to find the elementary or molecular composition of a specimen or the percentages of its constituents. Depending on the materials that have to be analysed is classified as organic and inorganic quantitative analysis, and depending on the task to be solved as elementary, molecular, and functional analysis; the first serves to determine elements (ions) present in a substance, and the second and the third ones give information about the amounts of radicals, compounds, and functional groups. The traditional quantitative analysis techniques are the gravimetric analysis and the titrimetric (volumetric) analysis.

quantum chemistry. A study of the structure and physicochemical properties of the ions, radicals, coordination compounds, etc. Includes the theory of chemical bonding,

valence, the electronic structure of molecules, their electric and magnetic properties.

quartz. A mineral, one of the most abundant forms of silica, SiO_2 . Hardness 7. Varieties: colourless transparent (rock crystal), violet (amethyst), smoky (cainngorm or smoky quartz), black (morion), yellow (citrine).

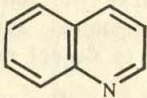
Properties: vitreous lustre, chemically stable. Practically insoluble in water and acids at 25°C , less stable to the action of alkalis, especially at elevated temperatures. Derivation: from quartz sand, sandstone, quartzite, and quartz veins.

Uses: in the glass and building industries. Admixtures of quartz increase strength and refractoriness of porcelain. Also used as an abrasive (grindstones, grinding wheels). Transparent quartz is used in electrical and radio engineering.

quartzite (quartz rock). A rock composed almost wholly (by 95 to 98%) of quartz grains. Used as tower packings in the manufacture of H_2SO_4 , HNO_3 , HCl , and as a material for refractory bricks (silica bricks).

quicklime. See *lime*.

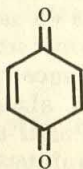
quinacrine. See *mepacrine*.

quinoline . An organic heterocyclic compound.

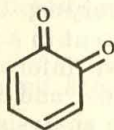
Used as a solvent for sulphur, phosphorus, etc., in the synthesis of organic dyes. Quinoline derivatives are used in medicine (plasmocid, quinine).

8-quinolinol. See *8-hydroxyquinoline*.

quinone. A cyclic diketone containing two carbonyl groups positioned ortho- or para- with respect to each other:



para-quinone



ortho-quinone

Used in dye manufacture.

R

radiation chemistry. A branch of chemistry which studies chemical transformations under the action of ionizing radiation, viz. alpha and beta particles and gamma rays, neutron and proton beams, etc. The radiation induces many chemical reactions such as polymerization, oxidation, various syntheses, and radiolysis of water.

radical [L *radix*, *radicis*, a root]. A group of atoms which maintains its identity in chemical transformations. Examples of inorganic radicals are the hydroxy group and acid residues. Typical organic radicals are hydrocarbon residues present in many substances; these residues are called hydrocarbon radicals, symbol R. Radicals of acyclic hydrocarbons are called alkyl radicals, and those of cyclic species aryl radicals. Names of many organic compounds are composed of the name of the hydrocarbon radical and atoms or groups of atoms present as substituents, e.g. CH_3Cl , methyl chloride; $\text{C}_2\text{H}_5\text{Br}$, ethyl bromide. In the free state, radicals (free radicals, R^\bullet) contain unsaturated valences (unpaired electrons) and can only exist for a short period of time because of their high reactivity (see *chain process*). Free radicals play an important part in polymerization, combustion, halogenation, in photochemical reactions, etc.

radioactivation analysis. An analytical procedure based on measuring radiation from radioactive isotopes formed in a sample subjected to bombardment by high-energy particles. It is very sensitive and used to determine admixtures in metals, alloys, semiconductors, and other materials.

radioactive element. A chemical element whose all isotopes are radioactive, viz. technetium, ^{43}Tc , promethium, ^{61}Pm , and all the elements with atomic numbers from 84 (^{84}Po), that is naturally occurring elements to uranium, ^{92}U , and synthetic transuranic elements.

radioactive indicator. A radioactive isotope used in science and technology for studying various phenomena and processes, see *isotope*, *tracer*.

radioactive isotope (radioisotope). An unstable isotope of a chemical element that undergoes spontaneous disintegration (decay) with the formation of one or several atoms of other element(s). All the chemical elements have ra-

dioisotopes, some 50 radioisotopes occur in nature, about 1500 synthetic isotopes were isolated from nuclear reactions. The radioactivity of a radioisotope is defined as the fraction of atoms decaying in a certain time and measured in curies; it is characterized by the half-life (the time taken for half a given number of atoms to be transformed), the type and the energy (hardness) of radiation. Radioisotopes are widely used in science and technology as radioactive tracers and as sources of radiation. Only few radioisotopes (cheap, long-lived, and emitting easily detectible radiation) are employed in technological processes. The most important fields of application of radioisotopes are: the radiation chemistry, the study of the mechanisms of various chemical processes including those involved in pig iron and steel manufacture, the study of wear resistance of details of mechanisms and cutting tools, the study of the diffusion and self-diffusion processes, etc. Radioisotopes emitting gamma rays are employed in gamma radiography to detect internal defects in materials and products.

radioactive series. Radioisotopes can be grouped in series in which each following member is formed by a nuclear transformation (alpha or beta decay) from the preceding one; the end elements in such series are stable isotopes. There are three radioactive series in nature, the uranium series with the long lived ^{238}U isotope as the parent isotope, the thorium series (^{232}Th), and the actinium series (^{235}U); the final isotopes are stable lead isotopes, ^{206}Pb , ^{208}Pb , and ^{207}Pb , respectively. The fourth series includes synthetic unstable isotopes.

radioactivity. A spontaneous transformation of unstable isotopes of an element into isotopes of another element accompanied by the emission of elementary particles or nuclei (e.g. helium nuclei). Radioactivity may involve alpha-decay or beta-decay usually accompanied by the emission of gamma rays, spontaneous fission of nuclei, etc. The rate of a radioactive transformation is characterized by the half-life of the starting isotope, $T_{1/2}$, the commonest radioactivity unit is curie. Radioactivity is used in science, technology, and medicine. See *radioactive isotope*, *radioactive element*.

radiochemical purity. The absence of foreign radioactive substances in a given radioactive sample.

radiochemistry. A branch of chemistry dealing with the chemical and physicochemical properties of radioactive substances.

radiolysis. The decomposition of chemical substances under the action of ionizing radiation; studied by radiochemistry.

radiometric analysis. The detection of radioactive isotopes in a given sample based on the determination of their half-lives and the type and energy of emitted radiation.

radium [L *radius*, a ray] Ra. A Group II radioactive element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 88, discovered in 1898 by the Curies in pitchblende. The longest lived isotope is ^{226}Ra ($T_{1/2} = 1617$ years), a member of the ^{238}U series, occurs in all uranium ores. The ^{226}Ra isotope decays with the emission of alpha rays and formation of radon, an inert gas: $^{226}\text{Ra} \rightarrow ^{222}\text{Rn}$.

Properties: a silvery white metal, resembles barium in its chemical properties, the oxidation state in compounds +2. Radium salts are less soluble than the corresponding barium salts.

Occurrence: in uranium ores, in many natural waters.

Uses: as a source of alpha particles in radium-beryllium neutron sources (beryllium emits neutrons under alpha irradiation), as a source of gamma rays in gamma radiography, in the manufacture of luminous paints, in medicine (radiotherapy, treatment of skin diseases, cancer).

radon [radium + on, as in neon etc.] Rn. A Group VIII element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 86, an inert (noble) gas. Discovered in 1900 by Dorn. The longest lived isotope is ^{222}Rn ($T_{1/2} = 3.8$ days), formed in alpha decay of ^{226}Ra , whence the name of the element (earlier called radium emanation, Em). Used in science and medicine (e.g. radon baths).

Raoult's laws (1882-1886). A decrease of the freezing point and an increase of the boiling point of a solution of a nonelectrolyte from a pure solvent are proportional to solution's molality. The laws are used to determine molecular masses of nonelectrolytes. Solutions of electrolytes do not conform to Raoult's laws because of the dissociation.

rare earth. An old name for rare earth element oxides.

rare earth element. Any of Group III elements including yttrium (Y, at. no. 39), lanthanum (La, at. no. 57), and

lanthanides (at. nos. from 58 to 71). The term rare earth elements has been in use since the end of the 18th century when minerals containing the elements of two subfamilies, the cerium subfamily (La, Ce, Pr, Nd, Sm, Eu) and the yttrium subfamily (Y, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu), were erroneously thought to occur only rarely in Earth's crust. The rare earth elements are however not rare: they are 10 times as abundant as lead, 50 times as molybdenum, and 165 times as tungsten. The elements are closely similar in their chemical and some physical properties because of a close similarity in the structure of the outer electronic shells of their atoms. Rare earth elements are metals; they are isolated by the reduction of their oxides and fluorides, by the electrolysis of anhydrous salts, and by other methods. Have various technological applications, are used in electronics, instrument manufacture, nuclear devices, mechanical engineering, chemical industry, metallurgy, etc. Large amounts of La, Ce, Nd, and Pr are used in glass manufacture in the form of oxides and other compounds to improve glass transmittance. They are also used as constituents of special glasses (for example, glasses transparent to IR and non-transparent to UV radiation, acid- and heat-resistant glasses). Rare earth elements are important materials for the chemical industry, they are used in the manufacture of pigments, lacquers, and dyes, in the petroleum industry (as catalysts). They are used in the production of some explosives, special steels and alloys, as absorbents of gases. See *lanthanides*.

rare earth metal. See *rare earth element*.

rare element. A conventional name for a large group (of about 50) of elements including lithium, beryllium, gallium, indium, germanium, vanadium, titanium, molybdenum, tungsten, rare earth elements, inert gases, etc. Most rare elements are metals, and for that reason the term rare metals is frequently used. The term owes its existence to a rather late discovery and utilization of these elements because of their low abundances, difficulties of the isolation in the pure form, etc. It would be incorrect to interpret the term literally because many rare elements such as titanium, vanadium, lithium are more abundant in Earth's crust than certain metals used by man from the earliest times, e.g. lead, tin, or mercury.

rare metal. See *rare element*.

rate of chemical reaction depends on the nature of the reagents, their concentrations, and the reaction conditions (temperature, pressure, the presence of a catalyst). Reaction rates vary within a very wide range, from almost instantaneous chain reactions to many-year processes of oxidation of organic substances. See *kinetics*.

reactions irreversible, reversible, chemical. See *irreversible reaction*, *reversible reaction*, *chemical reaction*.

reagent, chemical. A substance manufactured for analytical, scientific, etc. applications. Classified according to their purity and intended use (technical grade, reagent grade, high purity, instrument, research, commercial grade, etc.).

realgar. A mineral, arsenic disulphide, As_2S_2 .

Properties: transparent, brittle, poisonous; colour from aurora red to orange-yellow.

Uses: an ore of arsenic, used as an admixture to increase copper resistance to heat, in shot manufacture, as a constituent of type metal and cadmium-arsenic Babbitts.

rectification [L *rectus*, right + *facere*, to make]. The separation of mixtures of liquids via repeated evaporation and condensation in rectifying columns. Widely used in industry, e.g. in the manufacture of gasoline from petroleum ethanol manufacture.

redox methods. Titrimetric analytical procedures involving oxidation-reduction reactions. The redox potential of a system changes during the titration and undergoes a sharp change near the equivalence point. The methods are classified depending on the standard solution (titrant) (oxidizing or reducing agent) used in the titration (e.g. potassium permanganate, cerium, chromium, iodine compounds) (cerimetry, iodimetry, etc.).

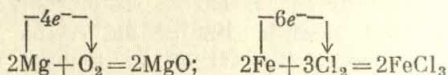
redoxmetry. See *redox methods*.

redox potential. The potential of an inert electrode (made of platinum or gold) inserted into a solution containing both the reducing and oxidizing agents with reference to the standard hydrogen electrode. For the reaction $\text{Ox} + ne^- \rightleftharpoons \text{Red}$ the dependence of the redox potential on the concentrations of the reagents (more accurately, on their activities) is given by the Nernst equation

$$E = E_0 + \frac{RT}{nF} \ln \frac{[\text{Ox}]^a}{[\text{Red}]^b}$$

where E_0 is the standard redox potential, n the number of electrons transferred from a reducing to an oxidizing agent, F the Faraday number (see *Faraday's laws*), R the gas constant, and T the absolute temperature. [Ox] and [Red] are the concentrations of the reagents. Redox potentials are determined by electrochemical methods and expressed in millivolts, mV, with reference to the standard hydrogen electrode.

redox reaction. A chemical reaction in which one of the participants undergoes oxidation (see *oxidation*) and the other one reduction (see *reduction*) with transfer of electrons from some atoms to other ones:



Redox reactions are accompanied by a redistribution of charges between the ions:



Redox reactions are widely used in science and in technological processes.

reduction. A chemical reaction reverse to oxidation. Atoms and ions undergoing reduction add electrons to decrease their valences (oxidation states). Examples are reduction of metal oxides to free metals by carbon, hydrogen, and other substances, reduction of carboxylic acids to aldehydes and alcohols, and hydrogenation of fats.

reforming. Cracking of various hydrocarbon oils or gases to form specialized products.

refrigerant. A fluid used in refrigerators: its vaporization at a reduced pressure causes cooling of a cold chamber. The most familiar refrigerants are ammonia, O_2 , CO_2 , Freons, ethyl chloride, $\text{C}_2\text{H}_5\text{Cl}$, etc.

regeneration [*L regeneraro*, to generate again]. A restoring of the initial properties of materials (lubricants, solvents) after they have been used.

repellent (*L repellere*, to drive back). Any substance used to drive away insects, as dimethyl phthalate.

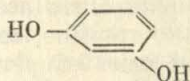
residual oil. Liquid or semiliquid products obtained as residues after the distillation of petroleum, a heavy petroleum fuel. Contains paraffins with twenty and more carbon atoms. Used in the manufacture of lubricants, asphalt,

and heavy fuel. Cracking and coking of residual oils give gasoline etc. products.

resin. An organic substance of a very complex composition.

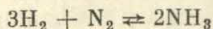
Natural resins are formed in metabolic processes in plants; much resin is produced by tropical and coniferous plants. Natural resins are used in the manufacture of soap, for sizing paper, in medicine and perfumery. In industrial applications natural resins are now being replaced by synthetic ones such as ureaformaldehyde resins (made by polycondensation of urea and formaldehyde), phenol-aldehyde resins (made by polycondensation of phenols and aldehydes, e.g. phenol-formaldehyde resins). Synthetic resins are used in the manufacture of various plastics.

resorcinol (resorcin, 1,3-benzenediol *)



Used in the manufacture of synthetic dyes, some polymers, and in medicine as a disinfectant in treatment of skin diseases.

reversible reaction. A chemical reaction that goes in two opposite directions simultaneously, e.g.



rhodium [L *Rhenus*, Rhine] Re. A Group VII element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 75, atomic mass 186.2. Occurs in nature as one stable isotope, ^{186}Re , and a weakly radioactive isotope, ^{187}Re . Was predicted by Mendeleev as eka-manganese. Discovered in 1925 by the Noddacks.

Properties: a high-melting silvery white metal, stable to corrosion. Occurs in compounds in various oxidation states, the most stable oxidation state is +7. Rhodium oxide, Re_2O_7 , shows acidic properties.

Occurrence: primarily in molybdenites.

Uses: rhodium alloys are used in electrical devices, in aircraft, and in rocket engineering. Rhodium is employed to produce corrosion-resistant coatings, in vacuum systems, as a catalyst.

rhodium [Gk *rhodon*, a rose, so called because of the colour of its salt solutions] Rh. A Group VIII element of the 6th period of the Mendeleev Periodic Table of Elements, atom-

ic number 45, atomic mass 102.905, a platinum family metal. One stable isotope, ^{103}Rh . Discovered in 1803 by Wollaston.

Properties: a silvery bluish metal, harder and higher melting than platinum and palladium. Very inactive chemically, insoluble in acids. The main oxidation state in compounds +3. Like platinum forms various complex ions. Occurrence: accompanies platinum and platinum family metals.

Uses: the production of stable to tarnishing coatings with a high reflective power. Alloys with platinum are used in the manufacture of chemical ware, in thermocouples, as catalysts, and in jewelry.

ribonucleic acid (RNA). A nucleic acid, a polymer of nucleotides incorporating phosphoric acid, ribose, and nitrogenous bases (adenine, cytosine, and uracil). Present in cytoplasm and microsomes of plant and animal cells; participates in biosynthesis of proteins.

ribose. A monosaccharide of the pentose series, $\text{C}_5\text{H}_{10}\text{O}_5$, contained in ribonucleic acid, adenosine, nucleotides, and other biologically important substances.

Rochelle salt. See *potassium sodium tartrate*.

rock crystal. A colourless, transparent variety of quartz, one of the crystalline forms of SiO_2 . Pure homogeneous crystals. Found in nature only rarely. Crystals of practical applicability should be not smaller than 3-5 cm edge-on. Occur in Brazil, Madagascar, and the USSR. Single crystals of SiO_2 are grown in autoclaves. The addition of Ge increases and the addition of Al decreases the refractive index of grown crystals. The addition of Fe^{2+} turns them green, Fe^{3+} brown, and Co blue. Used in radio engineering for ultrasonic oscillator plates, in optics (a material for prisms and lenses). Coloured rock crystals are semiprecious stones.

rock forming minerals. Minerals occurring as major components of rocks, e.g. feldspar, quartz, mica, and other igneous rocks; calcite, dolomite, various salts (sedimentary rocks).

rosin. A solid brittle transparent vitreous resin of a pale-yellow colour, a constituent of resins of coniferous plants which is left as a residue after spirits of turpentine has been distilled off. Insoluble in water, soluble in organic solvents. Used for sizing paper, in the manufacture of

soap, lacquers, sealing-wax, linoleum, putties, unguents, plasters, lubricants, plastics, fungicides, in soldering.

rubber. A high-molecular-weight hydrocarbon of the composition $(C_5H_8)_n$, a polymer of isoprene; occurs in the sap (latex) of the rubber tree (*Hevea brasiliensis*) and some other plants. Insoluble in hydrocarbons and their derivatives (gasoline, benzene, chloroform, carbon disulphide, etc.). Does not swell or dissolve in water, ethanol, and acetone. Even at room temperature adds oxygen which causes oxidative destruction (aging) of rubber and, therefore, a decrease of its elasticity and strength. At temperatures above 200 °C, rubber decomposes to low-molecular-weight hydrocarbons. The interaction of rubber with sulphur, sulphur chloride, and organic peroxides (vulcanization) results in the formation of cross-links between long linear rubber molecules (network structure). The resulting product retains elasticity in a wide temperature range. Not more than 1 per cent of rubber is used in the raw form (glues, footwear). More than 60 per cent is consumed in the manufacture of tires.

rubber cement. A solution of natural rubber in gasoline, used as an adhesive for rubber articles.

rubber, synthetic. A high-molecular-weight rubber-like material. Usually made by polymerization or copolymerization of butadiene, styrene, isoprene, chloroprene, isobutylene, and acrylonitrile. Like natural rubber, contains long linear chains, sometimes branched chains, whose molecular mass amounts to hundred thousands and even millions on an average. The polymer chains usually contain double bonds and owing to this the vulcanization of synthetic rubber results in the formation of network structures responsible for the physicochemical properties of rubber goods. Some kinds of synthetic rubber such as polyisobutylene, silicone rubber contain fully saturated molecules; the vulcanization of such rubbers is performed with the help of organic peroxides, amines, etc. Certain synthetic rubbers are superior to natural rubber in some properties, e.g. in stability to solvents, thermal stability, wearability and resistance to the action of light. Unlike natural rubber containing inhibitors of oxidation, synthetic rubber requires that such substances be introduced during its processing. Synthetic rubber is used in the manufacture of various articles for automobiles,

conveyer belts, footwear, accessories for work with organic solvents, etc.

rubber, vulcanized. An elastic material made by the vulcanization of rubber. Depending on the degree of vulcanization, may be soft, intermediate, and hard (ebonite). Used in the manufacture of more than 30 000 items.

rubidium [L *rubidus*, red, from the red lines in its spectrum] Rb. A Group I element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 37, atomic mass 85.47, an alkali metal; exists as a mixture of two isotopes, ^{85}Rb (stable) and ^{87}Rb (radioactive). Discovered in 1861 by Bunsen and Kirchhoff in the spectrum of lepidolite (a mineral).

Properties: a soft silvery white metal, very reactive, ignites in the air, reacts with water and acids with explosion. The oxidation state in compounds +1.

Occurrence: together with cesium in carnallite and lepidolite.

Uses: in photocells, daylight lamps. Rubidium salts are used in the analytical chemistry and in medicine.

ruby [L *rubeus*, red]. A mineral, a transparent variety of corundum, Al_2O_3 . Colour from pale pink to deep red, a precious stone. Synthetic rubies are used in the manufacture of jewel bearings, e.g. in watchmaking. Single crystals of ruby are used as laser material.

ruthenium [L *Ruthenia*, Russia: so called because first found in ores from the Urals] Ru. A Group VIII element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 44, atomic mass 101.07, belongs to the platinum family. Discovered in 1844 by Klaus.

Properties: a silvery white metal, resembles platinum, high-melting, very hard even at high temperatures. The most valuable properties are infusibility, hardness, chemical stability, the ability to accelerate some chemical reactions. The most typical oxidation states are +3, +4, and +8. Readily forms complex compounds.

Occurrence: found together with other platinum family metals.

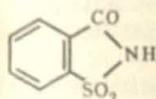
Uses: as a catalyst, a hardener for platinum and palladium (in the manufacture of instruments with sharp tips), a component of electric contact alloys, in jewelry, etc.

rutile TiO_2 . Natural titanium dioxide. Usually coloured (dark yellow, brown, red, or black). Used in the manu-

facture of ferro-titanium, white pigments, details with high dielectric constants. Synthetic rutile single crystals can be used as materials for rectifiers for high-temperature operating conditions, cut crystals to imitate diamond. Pure rutile crystals with certain admixtures are used in lasers.

S

saccharin (*o*-sulphobenzoic imide, benzosulphimide)



Properties: colourless crystals with a sweet taste, slightly soluble in water. Hydrated sodium salt of saccharin is 500 times as sweet as cane sugar.

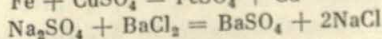
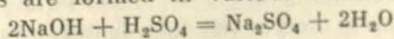
Derivation: from toluene.

Uses: medicine (a substitute for sugar in diabetes). Is not assimilated by organisms.

saccharose. See *sugar cane*.

sal ammoniac (ammonium chloride) NH_4Cl . Used in soldering, in galvanic cells, etc.

salt. A chemical compound formed by the substitution of a metal for the hydrogen atom(s) of an acid. Salts are crystalline solids with the ionic structure. They dissociate in aqueous solutions to give positive metal ions and negative ions of acid residues, and sometimes also hydrogen or hydroxyl ions. Salts are classified as neutral (e.g. Na_2SO_4 , MgCl_2), acid (hydro- salts, e.g. NaHSO_4 , NaH_2PO_4 , Na_2HPO_4), and basic (hydroxy- salts, e.g. $\text{Mg}(\text{OH})_2 \cdot \text{MgCO}_3$, $\text{CuCO}_3 \cdot \text{Cu}(\text{OH})_2$) (see also *double salts*). Salts are formed in various reactions, e.g.



Salts of carboxylic acids make up a separate group of compounds whose properties are substantially different from those of salts of inorganic acids.

salicylaldehyde (salicylal) *o*- $\text{HOC}_6\text{H}_4\text{COH}$.

Properties: a colourless liquid with a bitter almond-like odour and a burning taste.

Uses: in the organic synthesis and analysis, in the manufacture of dyes, as a fungicide, for the determination of fusel-oil in ethyl alcohol, in perfumery.

salicylic acid (*o*-hydroxybenzoic acid) $o\text{-HOC}_6\text{H}_4\text{COOH}$.

Properties: white needle crystals with a bitterish taste, soluble in hot water.

Occurrence: in the free state in leaves and flowers of certain plants, e.g. daisy.

Derivation: by the carboxylation of phenol.

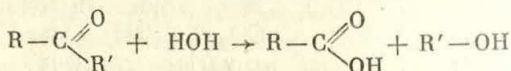
Uses: as a preservative for food-stuff, fruits, and wine; in the manufacture of dyes and pharmaceuticals; in medicine for treatment of infectious diseases (an antipyretic), rheumatism.

saltpetre: KNO_3 , saltpetre; NaNO_3 , Chile saltpetre; NH_4NO_3 , Norway saltpetre; $\text{Ca}(\text{NO}_3)_2$, lime saltpetre. Used as nitrogen fertilizers.

samarium (discovered in the mineral samarskite named after Russian mine official Samarkii) Sm. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 62, atomic mass 150.35, belongs with lanthanides. Discovered in 1879 by Lecoq de Boisbaudran, isolated in 1901. Properties: the oxidation states in compounds +2, +3. Compounds of Sm(II) are strong reducing agents.

Uses: an alloying component, the manufacture of dyes, phosphors, and catalysts; samarium oxides are used as constituents of protective ceramic coatings in nuclear energy devices.

saponification. The hydrolysis of an ester with the formation of an alcohol and an acid or its salt when the process is carried out in a solution of an alkali



The reaction is used in the manufacture of soap from fats: hence its name.

saturated hydrocarbons. Open-chain hydrocarbons where carbon atoms are linked with each other by single bonds. The general formula is $\text{C}_n\text{H}_{2n+2}$, e.g. CH_4 (methane), C_2H_6 (ethane), C_3H_8 ($\text{CH}_3-\text{CH}_2-\text{CH}_3$, propane). Saturated hydrocarbons are rather unreactive; their typical transformations involve various substitution reactions. Derived from petroleum and natural gas.

scandium [from Scandinavia] Sc. A Group III element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 21, atomic mass 44.956. One stable isotope, ^{45}Sc . Predicted and described as eka-boron by Mendeleev in 1870. Discovered in 1879 by Nilson during experiments on the separation of rare earth elements extracted from gadolinite (the mineral was first found in Scandinavia, and hence the name of the element).

Properties: a silvery metal with a characteristic yellowish cast. Rather reactive, reacts with oxygen at ambient temperature, dissolves in acids (HCl , H_2SO_4 , HNO_3). The oxidation state in compounds +3.

Occurrence: in many minerals as an admixture.

Derivation: extracted from uranium, tungsten, and tin ores, pig iron waste.

Uses: mostly used in alloys with various metals, e.g. in the manufacture of low-inductance ferrites for fast computers, in nuclear engineering, metallurgy, medicine, in the glass and chemical industries.

scattered elements. The chemical elements that do not occur as individual minerals or concentrated ores but are found as admixtures to minerals of other elements. They are usually extracted as by-products during processing of various ores and minerals (fossil coals, salts, phosphorites, etc.). Rubidium, thallium, gallium, indium, scandium, and germanium are examples of scattered elements.

scheelite CaWO_4 . A natural calcium tungstate. Colour grey, yellow, brown, and even red. An ore of tungsten. Scheelite crystals with lanthanide admixtures can be used in lasers.

sedimentary rocks. Rocks formed by the deposit of sediments of inorganic and organic substances followed by their compaction and transformations. According to their composition sedimentary rocks are described as carbonate, silicate, sulphate, halide, carbonaceous, etc. rocks. They make up more than 70 per cent of minerals of practical importance (coal, petroleum, peat, aluminium and manganese ores, phosphorites, potassium salts, a considerable proportion of iron ores, uranium ores, and ores of rare metals).

sedimentation. A settling of suspended solid particles to the bottom of a liquid under the action of gravity. The phenomenon is used in the sedimentation analysis (the technique for the determination of particle dimensions and

concentrations from the sedimentation rate). Widely employed for separating powders and concentrating ores.

selective reagents. Analytical reagents which give characteristic reactions only with few substances under certain conditions, e.g. with few ions. The higher the selectivity the better; for the use of selective reagents obviates the necessity to separate mixtures before analysing them. For example, Nessler's reagent is a selective reagent for the ammonium ion, and dimethylglyoxime for nickel.

selenium [Gk *selene*, the moon, so called by association with tellurium whose name derives from L *tellus*, the earth] Se. A Group VI element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 34, atomic mass 78.96. Discovered in 1817 by Berzelius.

Properties: like sulphur has several allotropic forms such as amorphous selenium and crystalline selenium. The latter is a brittle solid with a grey colour and metallic lustre. The grey form has an interesting property of increasing its electric conductivity substantially when subjected to the action of light; this property is utilized in selenium photocells. The oxidation states in compounds -2 , $+4$, $+6$. Stable to the action of oxygen, water, and dilute acids at room temperature. Dissolves in alkalis, concentrated nitric acid, and *aqua regia*. At elevated temperatures, combines readily with quite a number of elements. Hydrogen selenide, H_2Se , is a colourless, poisonous gas with a disagreeable odour, a weak acid in aqueous solutions. Salts of hydroselenic acid, selenides, resemble sulphides. Burning of selenium in the air gives SeO_2 , a solid substance; unlike SO_2 it mostly behaves as an oxidizing agent and readily undergoes reduction to free selenium. Strong oxidants can convert SeO_2 to selenic acid, H_2SeO_4 , a crystalline solid.

Occurrence: not abundant, occurs as an admixture to native sulphides (FeS_2 , PbS , etc.).

Derivation: from the flue dust obtained in burning pyrites in the manufacture of sulphuric acid.

Uses: the manufacture of rectifiers and photocells, the synthesis of selenides having semiconductor properties and used in thermocells, photoresistors, as phosphors.

semi-coking. The decomposition of solid fuels (coal, lignite, oil shale, and peat) in the absence of air at 500 to $550^\circ C$

(at temperatures about two times lower than that used in coking). The process yields semi-coke as a solid residue and volatile products. Semi-coke is used as inflammable solid fuel in industry and household.

semiconductor. A substance exhibiting an intermediate conductivity between those of conductors and insulators. Unlike metals semiconductors show an increase in conductivity with temperature; their conductivity also depends on the amount and nature of admixtures, applied electric field, light, and other external influences. Typical semiconductors are boron, carbon (diamond), silicon, germanium, grey tin, selenium, tellurium, silicon carbide (SiC), compounds of the $A^{III}B^V$ type where A stands for indium and B for antimony or arsenic, or A is gallium, B is antimony, or A is aluminium, B is antimony, compounds of two or three elements of which at least one belongs to Groups IV to VII of the periodic system, organic substances (polycenes, azoaromatic compounds, phthalocyanines, some free radicals, etc.). Strict requirements are imposed on purity of semiconducting materials: germanium manufacture involves control of 40 admixtures, 27 elements are determined in silicon. Percentages of admixtures should not exceed 10^{-4} to 10^{-9} . Semiconductors have wide practical applications.

sensitivity of chemical reactions (sensitivity of analytical procedures). The smallest amount of substance that can be detected using a given reaction or determined by a given analytical procedure.

separation in analytical chemistry. The most important analytical operations necessary because most analytical procedures are insufficiently selective and therefore many elements interfere with the determination of one in interest. The separation techniques include precipitation, electrolysis, extraction, chromatography, distillation, zone melting, etc. In the qualitative analysis, the separation of ions of elements is achieved by the use of group reagents which allow to reduce a difficult task of analysing complex mixtures to several simpler tasks.

serine $\text{CH}_2(\text{OH})-\text{CH}(\text{NH}_2)-\text{COOH}$. α -Amino- β -hydroxypropionic acid, found in plant and animal proteins, in casein (protein of milk). Transformed into cystine in the liver.

serpentine. A dense rock, contains 36 to 40% MgO , 40% SiO_2 , 5 to 13% Fe_2O_3 , and also Al_2O_3 and CaO . Colour green, often with green or white veins producing a pattern resembling that of snake's skin. Used as a refractory, a fertilizer, in building for decorative purposes. An ore of magnesium.

siderite. Native iron carbonate, FeCO_3 , a brownish-red mineral, dissolves in inorganic acids, transformed to brown hematite upon the oxidation. An iron ore.

Siemens-Martin process. See *open-hearth process*.

sieve analysis. The determination of fractions of particles of certain dimensions in dusts and granular materials by sifting the material through sieves with different cell dimensions.

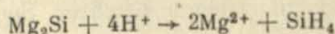
sigma- and pi-bonds. An approximate description of the types of covalent bonds in organic molecules. The sigma-bond has the maximum electron density along the axis passing through the atomic nuclei. The pi-bond involves orbitals directed normal to the bond direction; their overlapping results in the appearance of the electron density maxima above and below the sigma-bond plane. Consider ethylene, acetylene, and benzene as examples. The ethylene molecule, C_2H_4 , contains a double bond, $\text{CH}_2=\text{CH}_2$, its electronic formula is $\text{H}:\text{C}::\text{C}:\text{H}$.



The nuclei of all the ethylene atoms lie in the same plane. Three electronic clouds of each carbon atom are involved in covalent bonding with three other atoms lying in the same plane, the bonds making angles of about 120° with each other. The fourth valence electron cloud on carbon is directed normal to the molecular plane. These electronic clouds of the two carbon atoms overlap each other above and below the molecular plane to produce the second bond between the carbon atoms. The first and stronger covalent bond between carbon atoms is called sigma-bond, the second and weaker one is called pi-bond. The linear acetylene molecule contains two sigma-bonds between the carbon and hydrogen atoms, one sigma-bond between the carbon atoms which are also linked with each other by two pi-bonds: $\text{H}-\text{C}\equiv\text{C}-\text{H}$ ($\text{H}:\text{C}:::\text{C}:\text{H}$). The two pi-bonds are normal to the sigma- one and lie in mutually perpendicular planes. All the six carbon atoms of the cyclic benzene molecule,

C_6H_6 , lie in the same plane; the carbon atoms are linked by sigma-bonds in that plane with each other and with the hydrogen atoms; each carbon atom provides three electrons for sigma-bonding. Its fourth 8-shaped orbital is normal to the ring plane; it overlaps like orbitals of adjacent carbon atoms, the degree of overlapping being the same on both its sides. The result is the formation of one pi-electronic system comprising 6 electrons rather than 3 separate pi-bonds. The bonds between the carbon atoms in the benzene molecule are fully identical.

silanes (silicon hydrides). Compounds of silicon and hydrogen of the formula Si_nH_{2n+2} , readily decompose under the action of water ($SiH_4 + 2H_2O = SiO_2 + 4H_2$), vigorously react with oxygen (often with explosion). Made by the action of acids on metal silicides such as magnesium silicide:

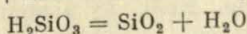
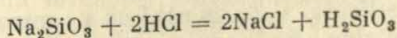


Unlike carbon chains the $\begin{array}{c} | \quad | \\ -Si-Si- \\ | \quad | \end{array}$ chains are unstable.

Silanes have higher densities, boiling and melting points than the corresponding hydrocarbons. The lower silanes are gases with a repulsive odour, the higher ones are volatile liquids, poisonous, soluble in organic solvents. Used in the organic synthesis, e.g. in the preparation of valuable organosilicon polymers.

silica. Silicon dioxide, occurs as quartz, cristobalite, etc. These forms undergo interconversions under certain conditions. Silica reacts readily with F_2 and HF, with many oxides to form metal silicates. Dissolves in alkalis. Used in the silicate industry, in the manufacture of glass, ceramics, concrete, silicate bricks, etc.

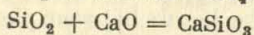
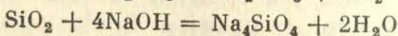
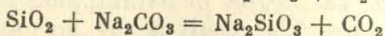
silica gel. A form of silica, SiO_2 , obtained by the action of hydrochloric or sulphuric acids on sodium silicate:



followed by drying the precipitate. The material has a well developed capillary structure. It is used to adsorb water vapour which undergoes condensation in silica capillaries, and also vapours of alcohol, acetone, benzene, and other organic liquids. Employed for the purification

of oils, fats, gasoline, kerosine, in chromatography, as carrier for various catalysts.

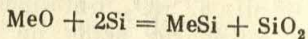
silicate. A salt of a silicic acid, made by fusing SiO_2 together with an alkali or a metal carbonate:



Very abundant in nature: Earth's crust mainly consists of silica, SiO_2 , and various metal silicates. Examples of native silicates are feldspars, mica, clays, asbestos, and talc. They occur as constituents of a number of rocks such as granite, gneiss, basalt, various varieties of shale. Many precious stones, e.g. emerald, topaz, aquamarine, are natural crystals of various silicates. See *glass, cement, glaze, enamel*.

silicic acids (hydrated silica). Very weak, slightly soluble in water substances. Salts of metasilicic, H_2SiO_3 ($\text{SiO}_2 \cdot \text{H}_2\text{O}$), orthosilicic, H_4SiO_4 ($\text{SiO}_2 \cdot 2\text{H}_2\text{O}$), and some other silicic acids, $\text{SiO}_2 \cdot n\text{H}_2\text{O}$, are known. Silica hydrates containing more than two water molecules per one SiO_2 unit can hardly exist as individual substances, but quite a number of their salts have been isolated. Silicic acids give colloidal aqueous solutions. Metal silicates are used in the manufacture of paper, in the textile industry, for treatment of water, as binding materials; they are very abundant in nature.

silicide. A compound of silicon and a metal. Silicides are formed at high temperatures. They are made either by the synthesis from the elements or by the reduction of a metal oxide with silicon:



Vanadium silicide, V_3Si , is used as a superconductor and rhenium silicide, ReSi , as a semiconductor. Many silicides are constituents of refractory materials (e.g. MoSi_2). Ferrosilicon has important practical applications.

silicon [L *silex, silicis*, flint] Si. A Group IV element of the 3rd period of the Mendeleev Periodic Table of Elements, atomic number 14, atomic mass 28.086, discovered in 1823 by Berzelius.

Properties: a dark-grey crystalline substance, the oxidation states in compounds +2 and, more often, +4, reacts with many substances at elevated temperatures, at 400 °C reacts with oxygen to give SiO_2 . Reduces many oxides upon heating. Dissolves in a mixture of hydrofluoric and nitric acids, rapidly dissolves in alkalis with release of hydrogen, reacts with many molten metals to form metal silicides; does not combine with hydrogen.

Occurrence: next to oxygen, the most abundant element; occurs as SiO_2 and metal silicates.

Derivation: very pure Si is obtained by the reduction of SiCl_4 with zinc, hydrogen, or by thermal decomposition of SiI_4 or SiH_4 . Silicon is manufactured by reducing silica with coke.

Uses: in metallurgy as a deoxidizer, contained in many iron, copper, aluminium, and other alloys. Also employed for the synthesis of organosilicon compounds and various other materials, in the manufacture of semiconductors, photocells, rectifiers, transistors, etc. Silicon and various silicates (clays, feldspar, mica, etc.) are used in large amounts in the manufacture of glass, cement, in the electric engineering, and other fields of industry.

silicon carbide SiC . One of the most important carbides used as an abrasive, etc.

silicon dioxide. See *silica*.

silicone. A group name for high-molecular-weight organosilicon compounds containing oxygen. Silicone rubber is a good electrical insulator, resistant to heat and to frost; remains elastic in the range -60 to $+200$ °C. It is widely applied in the manufacture of thermally resistant spacers, membranes, valves, details for projector units, electrical insulators, etc. Numerous organosilicon polymers are employed as lubricants stable to heating and freezing and fluids operating at temperatures of -100 to $+250$ °C, and to render various materials hydrophobic (e.g. fabrics, paper, glass, ceramics, building materials). They are also used in the manufacture of lacquers and dyes.

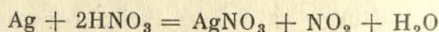
silicon monoxide SiO . A vitreous amorphous substance, stable to the action of oxygen under usual conditions.

Silumin. An alloy of aluminium and silicon containing up to 14% silicon. As strong as steel being far lighter than that material, very good for casting. Used in mechanical

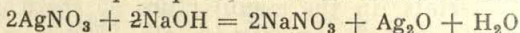
engineering (casting of motors, plungers, transmissions, etc.).

silver [Anglo-Saxon *soelfor*] Ag. A Group I element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 47, atomic mass 107.868, a noble metal known to the ancients. The use of native silver dates from 3000 years B.C. (Egypt, Persia, China).

Properties: a white soft metal, exceeds all other metals as a conductor of heat and electricity, the oxidation state in compounds +1. Rather unreactive, does not undergo oxidation in the air (tarnishing of silver is explained by the formation of black silver sulphide, Ag_2S). Unattacked by hydrochloric and dilute sulphuric acids, dissolves in nitric acid:



The addition of an alkali to a solution of silver nitrate results in the precipitation of dark-brown silver oxide:



Occurrence: found native and in ores (argentite or silver glance, Ag_2S ; cerargyrite, AgCl).

Uses: coinage, jewellery, table cutlery, laboratory equipment, storage cells, as catalyst. Silver salts of practical applicability are silver nitrate, AgNO_3 (the synthesis of other silver compounds), silver halides (photography). Silver nitrate is also used in the analytical chemistry for the determination of halide ions, in medicine (an antiseptic), for silvering mirrors, etc. Silver ions have a strong antiseptic action.

single crystal. A solid body comprising only one crystal. Most solids are aggregates of crystals. Single crystals are essential materials to optics, radioelectronics, semiconductor devices, watchmaking, the manufacture of lasers, etc.

slag. The fused product (a vitreous substance upon cooling) which separates in metal smelting and floats on the bath of metal, composed of waste rock and flux. Protects metal against the action of furnace gases, removes admixtures. Used in the manufacture of building materials (bricks, tiles), as a fertilizer. See *Thomas slag*.

slag concrete. A variety of light concrete with slag as a filler.

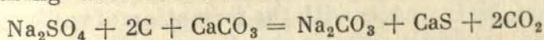
slime. The product usually containing noble metals which are separated as precipitates in the electrolysis of copper, zinc, and other metals.

smokeless gunpowder. An explosive with nitrocellulose as the major component.

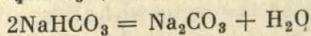
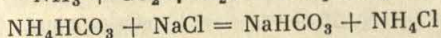
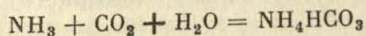
soap. A group name for salts of the higher fatty acids, first of all sodium salts of palmitic, stearic, and oleic acids (solid soaps). Potassium salts of the same acids are liquids. Made by saponification of fats by caustic alkalis.

soda. Any one of the forms of sodium carbonate. Calcined soda (soda ash) is anhydrous sodium carbonate, Na_2CO_3 ; sal soda is sodium carbonate decahydrate, $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ (other hydrated forms are $\text{Na}_2\text{CO}_3 \cdot \text{H}_2\text{O}$ and $\text{Na}_2\text{CO}_3 \cdot 7\text{H}_2\text{O}$); baking soda is sodium bicarbonate, NaHCO_3 . Soda occurs in lake waters, in the solid state (mainly sal soda).

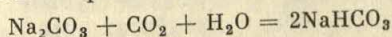
Derivation: in 1791, Leblanc suggested to prepare soda ash using the reaction



This technique is now abandoned in favour of the Solvay ammonia soda process (the second half of the 19th century):



Baking soda is made by saturating a solution of Na_2CO_3 with CO_2 under pressure:



Uses: soda ash is one of the most important products of the chemical industry, used in the manufacture of glass, soap, paper and cellulose, in the textile, petroleum, etc. industries. Baking soda is used in medicine, confectionary, in the manufacture of leather, rubber, in fire extinguishers.

soda caustic. See *sodium hydroxide*.

soda lime. A mixture of calcium hydroxide with sodium hydroxide, a white porous substance, strongly absorbs carbon dioxide gas and water vapour. Used in the determination of CO_2 , e.g. in the analysis of pig iron and steel for carbon, and to protect analytical solutions from the action of atmospheric CO_2 .

sodalite. A mineral, $3\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 6\text{SiO}_2 \cdot 2\text{NaCl}$, a sorbent, can participate in ion exchange reactions (like zeolites). Beautifully coloured, used as gem stone.

sodium [from soda] Na. A Group I element of the 3rd period of the Mendeleev Periodic Table of Elements, atomic number 11, atomic mass 22.9898, one stable isotope (^{23}Na); the radioactive isotope ^{24}Na ($T_{1/2} = 15$ h) is used in biological and medical studies. First isolated by Davy in 1807.

Properties: a silvery white soft metal with a high electrical conductivity, an alkali metal, highly reactive, the oxidation state in compounds +1, a strong reducing agent. Undergoes oxidation in the air and should therefore be kept under kerosene. Depending on the conditions reacts with oxygen to give sodium oxide, Na_2O , or peroxide, Na_2O_2 . Reacts vigorously with water, acids, halogens, sulphur, and phosphorus. Combines with hydrogen at elevated temperatures to give a salt-like hydride, NaH ; reacts with the formation of sodium amide, NaNH_2 . Sodium salts make flame yellow.

Occurrence: the sixth element in amount in Earth's crust, native sal soda and its washing properties were known to the ancients. Occurs in the atmosphere of the sun and interstellar medium, in sea water, in plants and animals. Found in the form of salts in Earth's crust (sodium chloride, NaCl , occurs as the mineral halite; sodium sulphate, $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$, as the minerals mirabilite, thenardite; sodium nitrate, NaNO_3 , as Chile saltpetre; sodium aluminium hexafluoride, Na_3AlF_6 , as cryolite; sodium tetraborate, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, as borax, etc.), contained in many silicates.

Derivation: by the electrolysis of molten sodium chloride or sodium hydroxide.

Uses: pure sodium and sodium alloys with potassium are used as heat transfer medium (e.g. in nuclear energy devices), sodium is used in metallurgy as a reducing agent in the manufacture of titanium, zirconium, and other metals, in the chemical industry (e.g. in the manufacture of synthetic rubber), in the organic synthesis.

See *sodium salts*.

sodium amide. A strong reducing and dehydrating agent, used in the synthesis of sodium cyanide, indigo, sulphapyridine, vitamin A, etc.

sodium chloride. See *sodium salts*.

sodium hydroxide (caustic soda) NaOH .

Properties: a white solid, an alkali in aqueous solutions.

Absorbs moisture and CO_2 from the air with avidity; dissolves in water with release of much heat. Destroys organic tissue, fabrics, and paper.

Derivation: by the electrolysis of aqueous solutions of NaCl (simultaneously with chlorine).

Uses: in the chemical, petroleum, textile, paper industries, and in the manufacture of soap.

sodium peroxide Na_2O_2 . A yellowish powder, obtained by burning sodium in oxygen, a strong oxidizing agent. Used in bleaching fabrics, wool, silk, paper pulp, straw, and in oxygen manufacture.

sodium phosphate, tribasic (trisodium orthophosphate) $\text{Na}_3\text{PO}_4 \cdot 12\text{H}_2\text{O}$. Used for softening water and to remove oil from metal and cloth, for washing glass and floor.

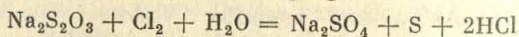
sodium salts. Sodium forms salts with all acids. Sodium arsenate, Na_3AsO_4 , and arsenite, NaAsO_2 (Na_3AsO_3) are pesticides; sodium bromide, NaBr , is used in medicine and photography; sodium dichromate, $\text{Na}_2\text{Cr}_2\text{O}_7$, is an oxidizing agent, used for tanning leather; sodium carbonate, Na_2CO_3 , and bicarbonate, NaHCO_3 , are given in separate entries; sodium nitrate (Chile saltpetre), NaNO_3 , is a nitrogen fertilizer; sodium nitrite, NaNO_2 , is employed in the synthesis of azo dyes and in medicine; sodium silicate, Na_2SiO_3 , is also called soluble or liquid glass (see a separate entry); sodium sulphate, Na_2SO_4 , is used in the manufacture of glass, paper, cellulose, leather, soap, and in the textile industry; sodium sulphide, Na_2S , in the manufacture of sulphide dyes, in the textile and leather industries, in flotation processes, in the analytical chemistry for separating element mixtures; sodium hydrosulphide, NaHS , is used in the manufacture of synthetic silk and leather; sodium polysulphides, Na_2S_n , in the flotation processes and agriculture; sodium sulphite, Na_2SO_3 , in photography, medicine, and in the manufacture of synthetic fibre; sodium hydrosulphite, NaHSO_3 , is a preservative, its other uses are bleaching and dyeing of fabrics; sodium thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$, is used in photography, medicine, and in the analytical chemistry; sodium fluoride, NaF , is a preservative for wood, is used in agriculture, in the manufacture of enamels, and as a flux; sodium phosphates have washing action, soften water, are employed in concentrating ores, in the food industry, etc.; sodium chloride (table salt)

is a starting material for the production of soda, sodium hydroxide, chlorine, and sodium sulphate, it is also used in medicine, agriculture, and for seasoning and preserving food.

sodium silicate (soluble glass, liquid glass, water glass). A vitreous substance, made by fusing together SiO_2 and soda. Aqueous solutions are used in the manufacture of cement resistant to the action of acids, for impregnating fabrics, in the preparation of fire-proof paints for wood, for hardening mellow ground, etc.

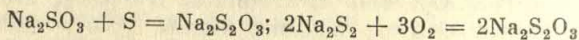
sodium thiosulphate (sodium hyposulphite, antichlor, hypo) $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$.

Properties: colourless transparent crystals, odourless, with a salty-bitter taste, very soluble in water, insoluble in ethanol. A strong reducing agent:



Forms neutral aqueous solutions which evolve sulphur upon the addition of an acid.

Derivation: by the reactions



Usually, hydrated crystals, $\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$, are prepared.

Uses: as a fixing agent in photography, in the textile industry to remove residual chlorine after bleaching, in leather manufacture, medicine and veterinary as an antidote against hydrogen cyanide, iodine, heavy metal salts, etc., in the analytical chemistry.

sol (from solution). A colloidal solution containing exceedingly small particles, of 10^{-5} to 10^{-7} cm dimensions, distributed uniformly in some medium (water, organic liquid, air or some other gas). Sols are intermediate systems between true solutions and dispersions (suspensions and emulsions).

solar oil. A high-boiling fraction obtained in the distillation of petroleum, a fuel for diesel engines with medium operating characteristics (engines for tractors, ships, etc.); it is also used as a lubricant and coolant in metal-work, for impregnating leather, in the textile industry.

solder. A metal or an alloy used in soldering to fill the gap between the details to be joined. Made of lead, tin, cadmium, copper, nickel, etc.

solid fuel. Combustible substances mainly composed of carbon such as bituminous coal, lignite, oil shale, peat,

and wood. The properties of a fuel depend to a considerable extent on its chemical composition, the percentages of carbon, hydrogen, oxygen, nitrogen, and sulphur. Different fuels taken in the same amount give different quantities of heat upon combustion. Fuel quality is therefore measured by its heating power, i.e. the maximum heat released by 1 kg of a fuel (bituminous coal has the largest heating power). The chief use of solid fuels is the generation of heat and other forms of energy for producing mechanical work. In addition to that, solid fuel can be subjected to distillation to obtain more than 300 various substances; reprocessing of lignite into valuable liquid fuels, gasoline and kerosine, is of great industrial importance.

solid solution. Solid homogeneous crystalline or amorphous substances of variable composition. Common in nature (feldspar, mica) and in industry (metal hydrides, carbides, nitrides, and oxides). Solid solutions of metals are very important materials because the formation of solid solutions results in a considerable increase in strength and hardness without an appreciable decrease in malleability; it also strongly increases electrical resistance of metals. Solid solutions are the major components of all alloys used in industry, e.g. structural, stainless, and acid-resistant steels, bronzes, brasses, light and superlight aluminium and magnesium alloys of high strength, high-electrical-resistance alloys. Among non-metallic solid solutions, the most important one is glass.

solid state reactions. Reactions occurring in the solid phase, e.g. analytical reactions between crystalline substances usually detected by colouration changes. Thus lead is detected by grinding its salts with potassium iodide: in the presence of lead, the mixture turns yellow because of the formation of solid lead iodide, PbI_2 . The solid-state analysis is a convenient technique for geologists and mineralogists, for qualitative analysis of fertilizers, soils, etc.

solubility. The ability of a substance to form homogeneous mixtures (solutions) with other substances. Solutions contain separate atoms, molecules, ions, or particles of dissolved compounds. Solubilities are measured by the concentration of a solute (dissolved substance) in its

saturated solution and expressed in per cent, weight, or volume units per 100 g or 100 ml of a solvent. Solubilities of gases in liquids depend on temperature and pressure, solubilities of solids and liquids depend practically on temperature alone.

solution. A homogeneous system of two or more substances. The composition of solutions is expressed by the concentrations of the components. Solutions can be liquid (salts in water), solid (a copper-nickel alloy used for coinage), and gaseous (solutions of gases, vapours, and solids in gases). Solutions of gases in each other are often called gas mixtures, e.g. air.

solution, concentrated. A solution of a substance with a high solubility whose concentration approaches that of the saturated solution.

solution, saturated. A solution containing a solute in the maximum concentration possible under given conditions.

solution, supersaturated. A solution containing a solute in a larger amount than that corresponding to the saturation. Excess solute precipitates readily. Supersaturated solutions are usually obtained by cooling solutions saturated at a higher temperature.

solution, unsaturated. A solution which contains a solute in the concentration below that of the saturated solution, i.e. a solution in which an additional amount of a given substance can be dissolved under given conditions.

solvate. See *solvation*.

solvation. An electrostatic interaction between solute and solvent particles (ions or molecules). Solvation in aqueous solutions is called hydration. The resulting molecular aggregates are called solvates (hydrates in water). A distinction is made between solvation (a combination of dissimilar, solvent and solute, particles) and association (the formation of aggregates of solute particles).

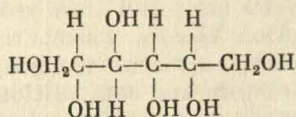
solvent. A compound or a mixture that can dissolve various substances. Examples of inorganic solvents are water, liquid ammonia, and nitric acid. Depending on their chemical nature organic solvents are divided into several groups such as hydrocarbons (benzene, toluene, xylene), hydrocarbon mixtures (gasoline etc.), chlorinated hydrocarbons (chloroform, carbon tetrachloride, chlorobenzene, dichloroethane, etc.), alcohols (methyl, ethyl, isopropyl, butyl alcohols), esters, ethers, ketones (acetone, methyl

ethyl ketone), compounds containing nitrogen and sulphur (nitromethane, nitropropane, nitrobenzene, carbon disulphide, nitroparaffin). Solvents readily dissolve plant and mineral oils, fats, bitumens, rubber, many natural and synthetic resins, waxes, and paraffins. They are widely used as diluents for dyes, lacquers, and for extraction. Most organic solvents are poisonous inflammable substances, volatile, and forming explosive mixtures with air.

solvolysis. A double decomposition reaction between a solute and a solvent. Solvolysis in water is called hydrolysis, in an alcohol alcoholysis, in ammonia ammonolysis, etc. Unlike solvation solvolysis results in the formation of new chemical compounds of a definite composition.

sorbent [*L sorbere*, to drink in]. A solid or a liquid used to absorb gases, vapours, or dissolved substances. Typical sorbents are activated carbon, silica gel, alumina, various ion exchangers, dibutyl phthalate, etc.

sorbitol (1,2,3,4,5,6-hexanehexol*, D-sorbite, sorbol). A hexahydric alcohol



A product of glucose reduction. Found in fruits, seaweed, higher plants. Used as a substitute for sugar in diabetes, in the manufacture of ascorbic acid.

sorption [*L sorbere*, to drink in]. A taking up of substances (gases, vapours, liquids, solids) from solutions by solids or liquids. *Adsorption*, *absorption*, and *chemisorption* are various types of sorption.

specific reagents. Organic and inorganic reagents that can be used to detect (determine) a certain compound (ion) under certain conditions. For example, starch is a specific reagent for free iodine.

spectral analysis (emission spectral analysis). A physical method for qualitative and quantitative determination of substance compositions from their emission spectra. The method is rather simple to use, rapid, does not require complex preliminary treatment of samples, can be applied to small amounts of substances (10 to 30 mg) to obtain data on a large number of components. Emission

spectra are obtained by vaporization of substances and heating them to 1000-10 000 °C to excite atoms. With conducting substances, spark or arc spectra are excited by alternating current. A sample is placed into a crater of a carbon electrode. Solutions are analysed with the help of flames of various gases. Qualitative and semi-quantitative analyses involve the detection of characteristic lines in the spectrum and estimation of the amounts of sought elements from the line intensities. Quantitative determination is based on experimental line intensity dependences on the concentration (for small concentrations). Emission spectral analysis is a sensitive method widely applied in chemistry, astrophysics, metallurgy, mechanical engineering, geology, etc. The method was suggested (1859) by Kirchhoff and Bunzen; it allowed to discover helium in the solar spectrum earlier than on earth.

spectrophotometry, absorption. A physicochemical method of studying solutions and solids based on measuring the absorption spectra in the ultra-violet (200 to 400 nm), visible (400 to 760 nm), and infra-red (above 760 nm) regions. Absorption spectra reflect the dependence of absorption intensity on the wavelength; they are applied to study the structure and composition of various compounds (complexes, dyes, analytical reagents, etc.), to determine the presence and amount of substances (in the determination of traces of elements in metals, alloys, and various industrial products). Absorption spectra are registered on spectrophotometers.

spectroscopy, infrared. See *infrared spectroscopy*.

sphalerite (blende, zinc blende) ZnS . A natural zinc sulphide, an ore of zinc, also recovered for cadmium, indium, and gallium. In large amounts used in the manufacture of zinc white. More and more zinc blende is consumed in the production of pure ZnS used as phosphor: ZnS activated by Ag, Cu is employed in kinescopes, radar, and oscillogram screens. Pure zinc sulphide is used in the manufacture of luminous paints and compositions, e.g. in instrument manufacture, in various signal devices.

spirits of wine. See *ethyl alcohol*.

spodumene. A mineral of the composition $\text{LiAl}(\text{Si}_2\text{O}_6)$, used as phosphor. The major application is the manufacture of lithium metal. Also used in the glass industry.

spot testing. A method of qualitative or semiquantitative chemical analysis. The substance to be studied and the reagents are taken in amounts of several drops; the analysis is carried out on porous paper or a plate, less frequently in a test tube. Used to check purity of various substances; for preliminary express analysis of ores and minerals in field-work, in research work.

stabilization. The term refers to various chemical processes. The stabilization of unstable, e.g. colloidal, systems is achieved by the addition of various substances (gelatin, proteins, or soap) which change the conditions of the interactions of main component particles with the medium. The stabilization of polymers and rubbers which are unstable towards the action of oxidants, irradiation, etc. is performed by the addition of various antioxidants. In photography, the stabilizing substances such as complex salts of Hg, Au, Pt and some heterocyclic compounds decelerate ripening of photographic emulsions and the formation of fog during storage of photographic materials.

stable isotopes. Those found in natural elements of the periodic system. More than 250 stable isotopes are known. The mass numbers of stable isotopes are determined by the mass spectrometric techniques. Stable isotopes are also used as isotopic indicators. See *isotopes*.

stainless steel. Steel containing more than 12% Cr, has a high corrosion resistance. To improve its mechanical properties, Ni, Mn, Mo, W, Nb, and other elements are added to stainless steel. Used in the chemical, petroleum industries, in metallurgy, mechanical engineering, aircraft, and also in household.

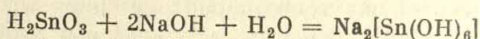
standard electrode potential (normal potential). The potential of an electrode in solution observed when the ions involved in an electrode process have activities equal to unity. Normal potentials are measured relative to the standard (normal) hydrogen electrode whose potential is taken for zero; expressed in volts.

standard sample. A reference sample for an analytical technique. Standard samples are substances whose compositions are known exactly, e.g. standard steel samples for spectral analysis containing small admixtures of alloying elements such as nickel, manganese, chromium, etc. Standard samples are employed in control of raw materials (ores, refractories, concentrates, etc.), intermediate

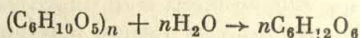
products, and products manufactured in mechanical engineering and metallurgy to determine their chemical composition.

standard solution. A solution with an accurately known concentration. Standard solutions are used in all titrimetric techniques employed for quantitative determination of substances and based on measuring volumes of standard solutions consumed in a certain reaction.

stannate. A salt of stannic acid, H_2SnO_3 . E.g. sodium stannate is obtained by dissolving stannic acid in a solution of sodium hydroxide:



starch $(\text{C}_6\text{H}_{10}\text{O}_5)_n$. A polysaccharide. Is formed in leaves of plants in the light, the end product of photosynthesis. Incorporates amylose and amylopectin, gives blue coloration with iodine, undergoes hydrolysis to give glucose as the final product:



Isolated from potatoes, used in glucose and ethanol manufacture, and also in the textile and food industries, in household.

states of aggregation. The solid, liquid, and gaseous states, e.g. ice, water, and vapour are the states of aggregation of water. A substance can exist in a certain state of aggregation under certain conditions (temperature, pressure). A transition from a given state of aggregation to another one may occur when the conditions are changed.

stearic acid $\text{C}_{17}\text{H}_{35}\text{COOH}$. One of the higher fatty acids. Properties: a wax-like solid, colourless and odourless, m.p. 70°C . Esters of stearic acid and glycerol and some other alcohols are very abundant in nature.

Occurrence: found in petroleum from some localities. Derivation: by the saponification of stearin obtained from animal fats.

Uses: in the organic synthesis, as an analytical reagent for the determination of Ca, Mg, and Li. Alkali metal stearates are surfactants.

stearin [Gk *stear*, stiff fat]. An organic product made from fats. Contains stearic acid and admixtures of palmitic, oleic, etc. acids. A solid semitransparent material, greasy to the touch, m.p. about 70°C . Used in soap manufac-

ture, in the paper, rubber, textile industries, and as a material for candles.

steel. An alloy of iron and carbon containing admixtures of manganese, silicon, sulphur, and phosphorus. The most familiar carbon steel contains 0.05 to 1.5% C, 0.1 to 1% Mn, up to 0.4% Si, up to 0.08% S, and up to 0.18% P. Alloyed steel contains larger admixtures or admixtures of other elements. The elements used to alloy steel are Cr, Ni, Mn, Cu, W, Mo, V, Co, Ti, Nb, Al, Zr, and Ta. Alloyed steels have good mechanical and physicochemical properties. They are used in the manufacture of details of mechanisms, instruments, cutting tools, stamps, etc. Stainless steels containing up to 12% Cr are resistant to corrosion in the air, in acids, alkalis, and solutions of salts. The addition of chromium, silicon, and aluminium makes steel heat-resistant, and the saturation of its surface by nitrogen (nitriding) strongly increases its wearability. Steel is usually made from pig iron by oxidizing some part of carbon contained there: this technique is applied most widely in the present day metallurgy. The other method is the reduction of iron in iron ores and the introduction of required amounts of carbon and other admixtures.

steel, stainless. See *stainless steel*.

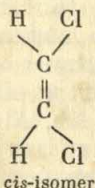
Stellite. Trademark for a series of cobalt-chromium-tungsten alloys. Used for applications requiring high resistance to abrasion and in the manufacture of metal-cutting tools.

stereochemistry. A branch of chemical study dealing with the spatial arrangement of atoms in molecules. If a molecule is considered as a three-dimensional body, possibilities of stereoisomerism arise. The differences between stereoisomers affect the rates and directions of chemical transformations, the physical properties of substances and their physiological action.

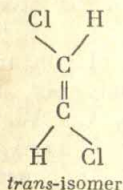
stereoisomerism (space isomerism). Isomerism caused by different arrangement in three-dimensional space of the atoms and atomic groups within a molecule having a given chemical structure. Stereoisomerism is typical for organic compounds and inorganic coordination compounds.

stereoisomers. Substances having the same composition and chemical structure but different arrangement of atoms or atomic groups in space and therefore different chemical and physical properties. A distinction is made between

geometrical (*cis*- [L *cis*, on this side] and *trans*- [L *trans*, across, over]) and **mirror** (optical) stereoisomers. For example, two geometrical isomers of 1,2-dichloroethylene are

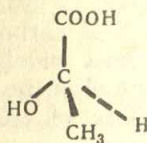
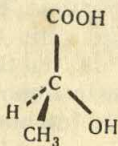


cis-1,2-dichloroethylene
m. p. -80.5°C ,
b. p. 59.8°C ,
density in the liquid state
 1.291 g/cm^3



trans-1,2-dichloroethylene
m. p. -50°C ,
b. p. 48.5°C ,
density in the liquid state
 1.265 g/cm^3

An example of optical isomerism:



The D form cannot be put in coincidence with the L form, which is its mirror image, by moving it in space. The two forms have identical chemical and physical properties except for optical activity.

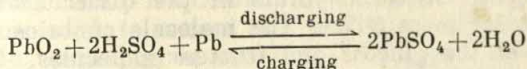
steroid. A complex organic substance of plant or animal origin. Steroids include bile acids, sterols, many important hormones (sex hormones, adrenal cortical hormones). Are important for living activity of organisms, used as drugs.

stibine (hydrogen antimonide) SbH_3 . A gas, a strong reducing agent. Poisonous.

stoichiometric formula. A chemical formula corresponding to the ideal integral composition of a chemical compound conforming to the requirements of the valences of constituent atoms. Small deviations from the stoichiometry are observed in solids, e.g. in iron sulphides and titanium oxides.

stoichiometry [Gk *stoicheion*, element, base]. The branch of chemistry dealing with proportions (weight and volume) in which substances react with each other, the derivation of chemical formulas and reaction equations. Stoichiometry is based on Avogadro's and Gay-Lussac's laws, on the laws of multiple proportions, constant composition, conservation of mass.

storage cell (storage battery, secondary cell, accumulator). A device for storing electricity. Storage cells accumulate chemical energy under the action of electric current and convert the stored energy into electricity when connected to external circuit. Consist of electrodes inserted into an electrolyte. After they have been discharged, storage cells can be recharged by passing through them electricity in the direction opposite to that of the discharge current; during charging, electric energy is again converted into chemical energy. The most familiar storage cells are those with lead, cadmium-nickel, silver-zinc, etc. electrodes. The reactions that go in lead storage cells are



strontium [from Strontian, town in Scotland where the mineral containing strontium was found] Sr. A Group II element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 38, atomic mass 87.62. Discovered in 1790 by Crawford. The ^{90}Sr ($T_{1/2} = 28$ years) radioactive isotope has found practical applications. This long-lived isotope is formed in fission of uranium (nuclear tests), dangerous to man.

Properties: a silvery metal, in its chemical properties resembles other alkaline earth metals (Ca, Ba). Turns flames red which property is utilized in pyrotechnics. The oxidation state in compounds +2.

Occurrence: the chief ores are strontianite, SrCO_3 , and celestite, SrSO_4 .

strychnine. An alkaloid, obtained from some tropical plants. A strong poison. Used in medicine in small doses to stimulate central nervous system in treating heart diseases, paralysis, decline of sight organs.

styrene (vinylbenzene, phenylethylene) $\text{C}_6\text{H}_5\text{CH}=\text{CH}_2$.

Properties: a colourless liquid, very soluble in organic

solvents, a good solvent for polymers. Highly reactive, easily polymerizes to a vitreous solid, polystyrene.

Derivation: by the dehydrogenation of ethylbenzene.

Uses: almost exclusively in the polystyrene manufacture.

subgroup of elements. See *Periodic Table of Elements*.

sublimation. A transition of a crystalline solid directly into the gas phase, without intermediate formation of the liquid phase. Naphthalene, iodine, camphor are examples of sublimable substances. Used in the purification procedures.

substrate. A substance upon which an enzyme acts.

succinic acid (butanedioic acid*). A dicarboxylic acid, $\text{HOOC}-\text{CH}_2-\text{CH}_2-\text{COOH}$, found in small amounts in many plants, amber. Increases growth of plants, accelerates ripening of maize. Used in the manufacture of plastics, resins, pharmaceuticals, for synthetizing purposes, in the analytical chemistry.

sucrose. See *sugar, cane and beet*.

sugar, cane and beet (saccharose, saccharum, sucrose) $\text{C}_{12}\text{H}_{22}\text{O}_{11}$. A carbohydrate of the disaccharide series, molecular mass 342.1. The molecule contains the residues of the glucose and fructose molecules.

Properties: colourless polyhedral crystals, very soluble in water, less soluble in organic solvents. Sweet taste.

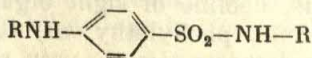
Occurrence: the most abundant disaccharide of vegetable origin; its chief sources are sugar cane and sugar beet where it is contained in the amounts of 15 and 19%, respectively.

Derivation: from sugar cane and sugar beet.

sugars. A group of carbohydrates with comparatively low molecular masses, very soluble in water, forming crystals. Carbohydrates with a sweet taste (sucrose, fructose, lactose, and glucose) are only called sugars by some; in recent years, a common practice has been to restrict the use of the term to monosaccharides.

Sulphacetamide (N-sulphanilylacetamide, sulphacyl). A drug for treating eye diseases.

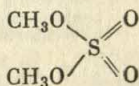
sulphanilamides. Sulphanilamide (*p*-aminobenzenesulphonamide, sulphamidyl), $\text{C}_6\text{H}_8\text{O}_2\text{N}_2\text{S}$, and other derivatives of sulphanilic acid of the general formula



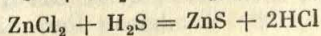
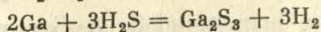
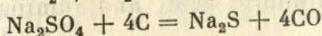
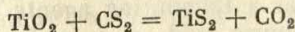
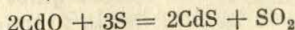
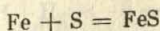
make up a group of organic compounds including about 6000 substances, e.g. sulphathiazole, sulphadimidine, phthalylsulphathiazole, of which 20 are used in medicine. Sulphanilamides are white or yellow crystalline powders with a somewhat bitter taste, slightly soluble in water, more soluble in organic solvents (alcohols, acetone), soluble in dilute solutions of acids and alkalis and in blood plasma. Amphoteric. Have a strong antibacterial action, used to treat pneumonia, meningitis, dysentery, etc.

sulphanilic acid (*p*-aminobenzenesulphonic acid, *p*-aniline-sulphonic acid) $p\text{-NH}_2\text{—C}_6\text{H}_4\text{—SO}_3\text{H}$. Made from aniline, used in the synthesis of dyes and as an analytical reagent.

sulphate. A salt of sulphuric acid, H_2SO_4 . Neutral sulphates are crystalline substances, mostly soluble in water (except for BaSO_4 , PbSO_4 , etc.). Often crystallize in the form of hydrates, e.g. various vitriols (blue vitriol or copper sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$; green (iron) vitriol or ferrous sulphate, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$; zinc vitriol, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$). Ammonium sulphate is used as a fertilizer, sodium sulphate in soap, paper, glass manufacture, copper sulphate in agriculture, etc. Metal hydrosulphates containing the HSO_4^- anion are used to convert substances insoluble in acids (e.g. calcined oxides of aluminium, chromium, iron) into soluble forms by fusing. Organic sulphates are esters of sulphuric acid, e.g. dimethyl sulphate:



sulphide. A compound of a metal and sulphur; the term is also applied to certain binary compounds of sulphur and non-metals, e.g. B, Si, P, and As. Sulphides are formed in various reactions:



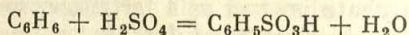
Many sulphides occur in nature, e.g. pyrite, FeS_2 , molybdenite, MoS_2 , or chalcopyrite, CuFeS_2 . Natural sulphides are used as ores of metals and in the manufacture of sulphuric acid. A large number of sulphides are semiconductors, e.g. CuS , CdS , Ga_2S_3 , In_2S_3 , and GeS_2 . Sulphides are also employed as phosphors (ZnS and CdS), in the organic chemistry, medicine, dye manufacture (e.g. lithopone or zinc sulphide white), agriculture, etc.

sulphinic acid. Any of organic derivatives of sulphurous acid of the general formula $\text{R}-\text{SO}_2\text{H}$.

sulphite. A salt of sulphurous acid, H_2SO_3 .

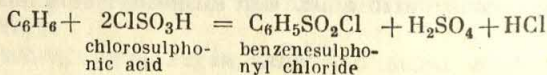
sulphite pulp. A pulp obtained by the digestion of wood chips with a solution of calcium hydrosulphite, $\text{Ca}(\text{HSO}_2)_2$, used in paper manufacture. Also recovered for ethyl alcohol, protein yeast, antibiotics, solvents, vanillin, and phenols.

sulphoacid, sulphonic acid. An organic compound containing the sulpho group, HSO_3 . Sulphonic acids are strong acids, very soluble in water, form soluble salts. Made by the sulphonation of organic compounds:



Used as intermediates in the manufacture of dyes, pharmaceuticals, surfactants, etc.

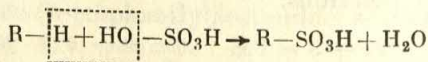
sulphochlorination. The substitution of the $-\text{SO}_2\text{Cl}$ group into organic substances.



Sulphuryl chloride can also be used in that reaction.

sulpho group. SO_3H .

sulphonation. The substitution of the sulpho group, $-\text{SO}_3\text{H}$, into organic substances with the formation of the $\text{S}-\text{C}$ bond:



The most familiar sulphonating agents are sulphur trioxide, SO_3 , sulphuric acid, and fuming sulphuric acid (oleum).

sulphur [L *sulphur*, brimstone] S. A Group VI element of the 3rd period of the Mendeleev Periodic Table of Ele-

ments, atomic number 16, atomic mass 32.064, known to the ancients.

Properties: a yellow solid, insoluble in water, soluble in carbon disulphide and benzene. Several allotropic forms of sulphur are known (rhombic, monoclinic, etc.). The oxidation states in compounds -2 , $+4$, $+6$, $+2$ (rare).

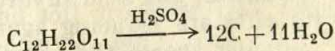
Occurrence: found native and in compounds, e.g. pyrite, FeS_2 .

Derivation: native sulphur is molten underground and raised to the surface by superheated water under pressure.

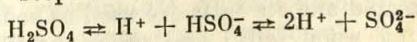
Uses: far the larger proportion of sulphur is used in the manufacture of sulphuric acid. Other uses are pulp and paper, carbon disulphide, dyes, matches, gunpowder, rubber vulcanization, medicine, agricultural fungicide. Purified sulphur with some organic admixtures (petroleum jelly, persic oil, etc.) is used to combat various skin diseases and as an antiseptic; these mixtures are also employed to destroy plant pests (spraying and dusting of plants), in cosmetics.

sulphuric acid (oil of vitriol, battery acid) H_2SO_4 .

Properties: a colourless oily liquid, density 1.84 (96% H_2SO_4). Absorbs moisture with avidity, dissolves in water with release of much heat because of the formation of the hydrates, $\text{H}_2\text{SO}_4 \cdot \text{H}_2\text{O}$, $\text{H}_2\text{SO}_4 \cdot 2\text{H}_2\text{O}$, and $\text{H}_2\text{SO}_4 \cdot 4\text{H}_2\text{O}$. Dissolves large amounts of SO_3 to give fuming sulphuric acid. Because of low volatility (b.p. 330°C) displaces more volatile acids from their salts. At elevated temperatures releases SO_3 which combines with moisture to produce fog of H_2SO_4 . Sulphuric acid is an effective dehydrating agent commonly used to dry gases; it causes charring of carbohydrates because of the abstraction of water:



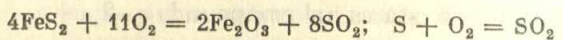
At elevated temperatures concentrated H_2SO_4 is a strong oxidizing agent. Sulphuric acid is a strong dibasic acid, undergoes stepwise dissociation in aqueous solutions:



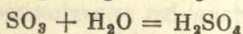
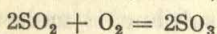
Forms sulphates (neutral salts) and hydrosulphates (acid salts). Alchemists produced sulphuric acid by heating

iron vitriol, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, and for that reason it is sometimes called oil of vitriol.

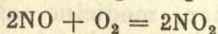
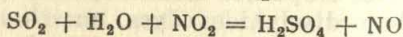
Derivation: by the contact process which includes the calcination of pyrite or combustion of native sulphur to obtain SO_2 :



Sulphur dioxide is then oxidized to SO_3 in the presence of platinum as catalyst (400°C):



The other industrial method of sulphuric acid manufacture is based on the chamber process:

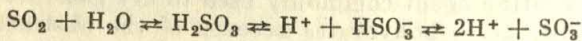


Uses: one of the most important products of the chemical industry, used in the manufacture of acids, alkalis, salts, fertilizers, chlorine, etc. Also employed in the purification of substances obtained from petroleum and coking products (benzene, toluene), in the manufacture of dyes, in etching metals. The most important sulphate fertilizers are superphosphate and ammonium sulphate.

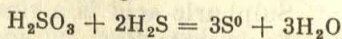
sulphuric acid, fuming (oleum, pyrosulphuric acid). An about 20% solution of sulphur trioxide in sulphuric acid, used in the organic synthesis (e.g. in the manufacture of dyes, caprolactam, and explosives) and for purification of petroleum products.

sulphuric ether. See *diethyl ether*.

sulphurous acid H_2SO_3 . A weak dibasic acid, exists only in dilute aqueous solutions:



Forms neutral (sulphites) and acid (hydrosulphites) salts. The acid and its salts are reducing agents. In reactions with stronger reducing agents than itself, the acid can act as an oxidizing agent:



Sulphurous acid and its salts are used as reducing agents, for bleaching wood, silk, and other materials that are destroyed by bleaching with strong oxidizers such as chlorine, as preservatives for fruits, vegetables, etc.

Calcium hydrosulphite, $\text{Ca}(\text{HSO}_3)_2$, is used in the digestion of wood: its solution dissolves lignin, the substance that binds cellulose fibres, to separate the fibres from each other and produce sulphite pulp used in paper manufacture.

sulphuryl chloride SO_2Cl_2 . The product of the addition of chlorine to sulphur dioxide, SO_2 . Used in the organic synthesis (see *sulphochlorination*).

superphosphate. The commonest phosphorus fertilizer made by the decomposition of natural phosphates (apatite, phosphorite) or bone-meal under the action of sulphuric acid. The product is a mixture of calcium phosphates, monobasic ($\text{Ca}(\text{H}_2\text{PO}_4)_2$) and gypsum, CaSO_4 . Triple superphosphate is made by the decomposition of phosphate rock with phosphoric acid. It contains $\text{Ca}(\text{H}_2\text{PO}_4)_2$ and a small percentage of free H_3PO_4 (50% available in P_2O_5). The neutralization of superphosphate by ammonium or the addition of ammonium nitrate solution to superphosphate gives ammoniated superphosphate (ammonium nitrate is a valuable component of compound fertilizers). The decomposition of phosphate rock by mixtures of H_2SO_4 and H_3PO_4 gives concentrated superphosphate.

surfactant, surface active agent. Any substance that decreases interfacial tension between two liquids or between a liquid and a gas. Used in flotation, in the preparation of emulsions, etc.

suspension [*L. suspensus*, hung up]. A solid distributed in a liquid but not dissolved in it, e.g. a turbid system formed when small clay particles are distributed in water. Differs from colloidal solutions by larger dimensions of particles. Unstable, undergoes spontaneous aggregation of particles which can be hindered by the addition of stabilizing agents. Suspensions are involved in many geological and soil processes (the formation of sedimentary rocks, alluvia, etc.). Also play an important part in the manufacture of paper, rubber, lacquers, dyes, etc.

sylvinite, $m\text{KCl} + n\text{NaCl} + \text{admixture}$ s. A mineral with a variable potassium to sodium ratio. Contains much sand, clay, gypsum, etc. Varicoloured. Dissolves in water almost fully (except for admixtures). A very important material for the manufacture of potassium chloride, also used as a fertilizer.

sylvite (sylvine) KCl. A natural potassium chloride, occurs together with other potassium minerals (usually together with sylvinite).

symbols of chemical elements are used as abbreviations in naming the chemical elements, usually the first letters of their Latin names, e.g. Cu, copper (from L *cuprum*); Ag, silver (from L *argentum*); Fe, iron (from L *ferrum*); etc. The system of chemical symbols was suggested in 1811 by Berzelius. Symbols reflect not only the qualitative but also the quantitative composition of substances because in each symbol, the atomic mass of the element is implied.

synthesis. The preparation of complex substances from simpler ones; the term is often applied to the preparation of new elements by nuclear reactions.

T

tabun. An organophosphorus compound, a colourless mobile liquid, b.p. 220 °C, slightly soluble in water, very soluble in organic solvents. Liable to hydrolysis, readily reacts with solutions of ammonia and amines. A nerve gas.

talc. Magnesium silicate, $4\text{SiO}_2 \cdot 3\text{MgO} \cdot \text{H}_2\text{O}$.

Properties: a white or greyish crystalline powder, odourless and tasteless, greasy and slippery to the feel, insoluble in water.

Uses: in the paper, rubber, soap, textile, ceramic industries, in cosmetics and perfumery, in medicine for powdering.

tannin. Naturally occurring substances found in nutgalls, tree barks (e.g. oak), tea, etc.

Properties: a faintly yellowish amorphous powder soluble in water and glycerol; forms colloid acid solutions with a strong tanning action.

Uses: in tanning leather, as a mordant in dyeing, as an antiseptic in medicine in treating intoxications with lead, mercury, etc. salts.

tanning. The process of making leather from hides under the action of tanning agents, which are in part distributed in the material and in part combine with material's functional groups. Tanning results in the formation of

bonds of various types between protein structure elements and tanning agent molecules (hydrogen, electrovalent, covalent bonds).

tanning agents. Chemical compounds used to denature proteins in hides, gelatin, or casein; affect the colloidal state of proteins (cause hardening, hinder swelling in water). Examples of inorganic tanning agents are chromium(III) basic salts and alum. They are used in leather manufacture. Organic tanning agents may be of plant or animal origin or synthetic. Formaldehyde is used as a tanning agent in the manufacture of white leather; whale oil is a tanning agent of the animal origin used in dressing chamois.

tantalum [Gk *Tantalos*, mythological character] Ta. A Group V element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 73, atomic mass 180.948. Discovered in 1802 by Ekeberg.

Properties: a grey metal with a bluish cast, m.p. 2850 °C, hard but not brittle, workable. Very stable to the action of acids and other aggressive substances being superior to platinum in that respect. Reacts with fluorine at room temperature, only at elevated temperatures with other substances such as sulphur or halogens. The principal oxidation state +5.

Occurrence: does not occur native, found as admixtures to certain minerals (columbite, tantalite, etc.).

Uses: in surgery to fasten broken bones (tantalum does not irritate living tissue and causes no harm to organisms), in various heat-resistant, hard, and high-melting alloys (rocket engineering, supersonics). In the manufacture of chemical instruments, laboratory ware, and crucibles.

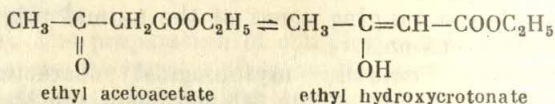
tar. A liquid product obtained by the destructive distillation of coal, lignite, wood, and shale. A complex mixture of organic substances whose composition depends on the starting material and processing conditions. See also *coal tar*.

tartaric acid (dihydroxysuccinic acid) $\text{HOOC}-\text{CHOH}-\text{CHOH}-\text{COOH}$. A dibasic acid, forms three stereoisomers. Used in the food industry, in medicine, and in the analytical chemistry. Metal tartrates are used in medicine, dyeing, etc.

tartrate. A metal salt or ester of tartaric acid.

tautomerism [Gk *tauto*, the same + Gk *meros*, a part].

A phenomenon of reversible isomerism when two or more isomers readily undergo interconversions. A substance characterized by tautomerism exists in the state of a tautomeric equilibrium and contains all its isomeric forms in a certain ratio. Tautomerism usually involves H atom shifts between various atoms of the same compound. The most familiar example is ethyl acetoacetate which is an equilibrium mixture of the esters of acetoacetic and hydroxycrotonic acids:



Tautomerism is involved in many chemical and technological processes, especially those used in the manufacture of pharmaceuticals and dyes (vitamin C etc.). It plays an important role in processes in vivo.

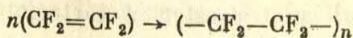
technetium [Gk *technetos*, artificial] Tc. A Group VII radioactive element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 43. First produced in 1937 by Perrier and Segre by bombarding ^{92}Mo with deuterons [$\text{Mo}(d, 2n)^{92}\text{Tc}$]. The only route to technetium is nuclear reactions; it is found in the fission products of uranium. The stablest isotope is ^{99}Tc ($T_{1/2} = 1.2 \times 10^5$ years).

Properties: a silvery brown dense metal, the closest analogue of rhenium, forms compounds in all the oxidation states from 0 to +7. Insoluble in hydrochloric acid; readily dissolves in nitric acid and in *aqua regia* to form heptavalent technetium compounds.

Uses: inhibition of corrosion; a valuable structural material for nuclear energy devices.

technical analysis. A combination of physical, physicochemical, and chemical methods of analysis of raw materials, intermediate and final industrial products used in various technological schemes, e.g. in the manufacture of steel or fertilizers. The methods of technical analysis are usually standardized.

Teflon. Trademark for polytetrafluoroethylene resins:



A white paraffin-like substance, transparent in thin layers, very resistant to heat and frost, elastic at temperatures of -250 to $+250$ °C, a good electrical insulator. Has a higher chemical stability than all the other synthetic materials and noble metals, unattacked by alkalis, acids, and even *aqua regia*. Used in the chemical and food industries, in electrical engineering, in medicine. Can be used in nuclear engineering.

tellurium [L *tellus*, the earth] Te. A Group VI element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 52, atomic mass 127.60. Discovered in 1782 by Muller von Reichenstein.

Properties: Amorphous powder or light-grey crystals with metallic lustre and near metallic conductivity of heat and electricity; has semiconductor properties. The typical oxidation states in compounds $+4$, $+6$, -2 . Combines with halogens in the cold, with oxygen when heated in the air. Does not react with hydrogen, nitrogen, and carbon. Readily combines with metals to form tellurides. Occurrence: found in a considerable number of minerals (calaverite, hessite, etc.).

Derivation: from copper electrolyte slimes and lead and zinc manufacture wastes.

Uses: one of the most important applications is the synthesis of tellurides (salts of hydrotelluric acid) and their alloys which are semiconducting materials; also used as an alloying element to lead, a vulcanizing agent, as a colouring agent in glass and ceramics, in microbiology.

terbium [from Ytterby, a village in Sweden] Tb. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 65, atomic mass 158.9254; a lanthanide.

Properties: reactive like all the lanthanides; the oxidation states in compounds $+3$, $+4$.

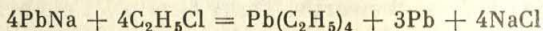
Uses: together with other lanthanides is used in various alloys, as a constituent of phosphors, in the manufacture of glass, lacquers, pigments, etc.

test analysis. The determination of noble metals (gold, silver, platinum, etc.) in ores, in the products obtained from ores, ingots, articles, etc. using chemical and metallurgical techniques (melting, cupelling).

test paper. Papers used for an approximate determination of pH values in solutions, for rapid detection of certain

substances in solutions and gases. Made by impregnating porous papers with solutions of indicators or other reagents and drying. A piece of such paper is introduced into a solution or gas to observe a change in its colouration.

tetraethyllead $(C_2H_5)_4Pb$. An organolead compound, used to prevent knocking in internal combustion engines. Prepared by the reaction



Volatile, poisonous. Now replaced by less toxic anti-knocks.

textolite. A laminated plastic made of cotton sheets bonded with phenol- or cresol-formaldehyde resins. Manufactured under pressure of 5×10^6 to 10^7 Pa.

thallium [Gk *thallos*, a young, green shoot: from the green line in its spectrum which led to its discovery] Tl. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 81, atomic mass 204.37. Discovered in 1861 by Crookes by the spectral method. Natural thallium contains two isotopes, ^{203}Tl and ^{205}Tl .

Properties: a bluish-white lead-like metal, tarnishes in the air. Does not react with water, but readily dissolves in acids. The oxidation states in compounds +1, +3. Thallium hydroxide (thallous hydroxide), $TlOH$, is a strong base, whereas thallic hydroxide, $Tl(OH)_3$, shows only weak basic properties. Most univalent thallium salts are readily soluble in water except for thallous halides, $TlCl$, $TlBr$, and TlI , which like the corresponding silver salts are almost insoluble and sensitive to the light.

Occurrence: a scattered element, occurs as traces in various rocks.

Derivation: from sulphide ores of nonferrous metals; the chief source is flue dust from zinc smelting.

Uses: thallium compounds are used in photography, medicine, in the manufacture of optical glasses with high refractive indices. Thallous sulphide is used in high-sensitivity photocells, thallous sulphate as a rodent poison. Thallium metal is a component of some alloys for bearings and alloys resistant to acids.

theory of molecular orbitals (MO) gives an idea of the distribution of electron density and explains some properties

of molecules. The quantum mechanical equations describing atomic systems are extended in this theory to a more complex system, the molecule. Like atoms molecules are characterized by discrete states of electrons (molecular orbitals) which are involved in self-consistent motion in the field created by other electrons and atomic nuclei. Each orbital is characterized by a set of quantum numbers describing electrons in a given energy state. Unlike one-centre atomic orbitals many-centre molecular orbitals are shared by two or more nuclei. By analogy with the *s*-, *p*-, *d*-, and *f*- atomic orbitals the molecular orbitals are denoted by the Greek letters σ -, π -, δ -, and γ -. The molecular orbitals are formed as combinations of atomic orbitals at small atomic spacings, e.g. two two-centre orbitals of the H_2 molecule are formed from two *s*-orbitals of the H atoms; one of these has a lower and the other a higher energy than the initial orbitals: they are called the bonding and the antibonding orbital, respectively. The electrons on the bonding orbital spend most of the time between the nuclei and cause attraction of nuclei to each other, while antibonding electrons mostly dwell behind the nuclei and give rise to repulsive forces. The distribution of electrons over molecular orbitals determines the bond order, bond's energy, atomic spacings, the magnetic properties of molecules, etc.

thermal dissociation. A reversible chemical reaction, a breaking up of a compound into two or more components, e.g. the decomposition of hydrogen iodide into hydrogen and iodine, silver oxide into silver metal and oxygen. Conforms to the mass action law. Widely used in chemical and industrial processes.

thermite. A mixture of aluminium metal powder and ferrosferic oxide, Fe_3O_4 . Develops a temperature of 2300 to 2700 °C when ignited with the help of a mixture of BaO_2 , Mg, and Na; releases much heat. Used in welding iron and steel (e.g. rails), as an incendiary mixture, etc. Can contain other than iron oxides, e.g. vanadium and chromium oxides. Such mixtures are used to prepare ferrochromium and ferrovandium.

thermochemistry. A branch of chemistry dealing with thermal effects of chemical transformations.

thermocouple. A device sensitive to heating and made of two welded dissimilar metals (Pt—Rh, Pt—Ir, etc.) or

semiconductors. Heating of a thermocouple results in the appearance of emf depending on the materials and temperature. Used to measure temperatures of up to 2000 °C and higher.

thermodynamics, chemical. A branch of science studying chemical reactions and phase transitions (dissolution, vaporization, and crystallization of neat substances and solutions and the reverse processes), and transfer of energy from one form to another and from one part of a system to another one in various chemical processes, etc. Includes thermochemistry, the theory of chemical and phase equilibria, the theory of solutions, of electrode processes, thermodynamics of surface phenomena as its most important parts. Based on the general laws of thermodynamics (thermochemistry relies on the first law of thermodynamics, the theory of equilibria on the second, and so on).

thio [Gk *thei-*, *theo-*, sulphur] in chemical names, indicates the presence of sulphur.

thio alcohols. See *thiols*.

thiocyanate. A salt or an ester of thiocyanic (sulphocyanic) acid. Inorganic thiocyanates such as potassium thiocyanate, KSCN, and ammonium thiocyanate, NH_4SCN , are used in the analytical chemistry for the determination of Fe^{3+} , which forms a blood-red compound with SCN^- , Cu^{2+} , and other cations. They are also used in agriculture as insecticides and fungicides.

thio ethers (dialkyl- or diaryl sulphides). Compounds with two hydrocarbon radicals attached to sulphur, e.g. $\text{CH}_3\text{—S—CH}_3$ (methylthiopropene). Used as antioxidizing and stabilizing admixtures to fuels for internal combustion engines, lubricants, latex, as pharmaceuticals, dyes, and solvents.

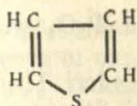
thiols. Compounds containing the —SH group attached to a hydrocarbon radical, e.g. ethanethiol, $\text{C}_2\text{H}_5\text{SH}$. Sometimes called mercaptans.

thionyl chloride (sulphurous oxychloride) SOCl_2 . Reacts with water to give sulphurous and hydrochloric acids.



Used in the manufacture of dyes, pharmaceuticals, as a chlorinating agent.

thiophene



A five-membered heterocyclic compound containing one sulphur atom in the ring. Resembles benzene in its chemical properties. Manufactured from shales and petroleum containing sulphur. Various thiophene derivatives are used as pharmaceuticals, growth stimulators, herbicides, polymers, perfumes (synthetic musk), analytical reagents for separating elements (thenoyltrifluoroacetone), etc.

thio salts. Salts of thio acids. Sodium thioarsenate, Na_3AsS_4 , and thioarsenite, Na_3AsS_3 (the salts of the corresponding arsenic thio acids), are used in agriculture and in the analytical chemistry.

thiosulphate. A salt of thiosulphuric acid, $\text{M}_2\text{S}_2\text{O}_3$. Thiosulphates are stable, colourless, and very soluble in water substances. See *sodium thiosulphate*.

thiosulphuric acid $\text{H}_2\text{S}_2\text{O}_3$. An unstable dibasic acid: $\text{H}_2\text{S}_2\text{O}_3 = \text{SO}_2 + \text{S} + \text{H}_2\text{O}$. Its salts, e.g. sodium thiosulphate, have found practical applications.

thiourea (thiocarbamide) $\text{S}=\text{C}(\text{NH}_2)_2$. White crystals with a bitter taste, soluble in water. Analogous to urea in its chemical properties. Made in the reaction of H_2S with cyanamide, NH_2CN . Used in the organic synthesis, in the manufacture of pharmaceuticals (e.g. sulphapyridine), and as a growth accelerator.

Thomas and Gilchrist process for steel. A method for the production of steel which utilizes an oxidizing gas mixture (compressed air or a mixture of oxygen with carbon dioxide and water vapour) blast through molten pig iron rich in phosphorus. The process is carried out in a converter. Pig iron is transformed into steel because of the oxidation of admixtures contained in pig iron (silicon, manganese, carbon, phosphorus, in part sulphur) by oxygen. The method was suggested by Thomas in 1878. If pure oxygen is used the process gives steel which is superior even to steel from the open-hearth process.

Thomas slag (basic slag, basic cinder, Thomas metal). A slag produced in the conversion of pig iron of high phosphorus content into steel, approximate composition $\text{Ca}_3(\text{PO}_4)_2$.

CaO, formed in the reaction of P_2O_5 with lime, CaO. A valuable fertilizer.

thorium [ON *Thor*, the god of thunder] Th. A Group III natural radioactive element of the 7th period of the Mendeleev Periodic Table of Elements, atomic number 90, atomic mass 232.038, practically consists of only one isotope, ^{232}Th ($T_{1/2} = 1.39 \times 10^{10}$ years). Discovered in 1828 by Berzelius. The first member of the actinide family, the parent isotope of the thorium series.

Properties: a silvery metal, tarnishes in the air with the formation of a ThO_2 film, soluble in HCl. The oxidation state +4.

Occurrence: the chief ore is monazite.

Uses: widely used in nuclear energetics being converted to the nuclear fuel ^{233}U when bombarded by neutrons, employed in X-ray devices. Thorium alloys are applied as materials for jet engines, guided missiles, radar sets. Thorium oxide is a refractory.

thulium [Gk *Thoule*, Thyle, the northernmost region of the world] Tm. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 69, atomic mass 168.934, a lanthanide, one stable isotope, ^{169}Tm . Discovered in 1879 by Cleve.

Properties: typical for lanthanides.

Occurrence: as admixture to some minerals, e.g. monazite.

Uses: mostly the radioactive isotope, ^{170}Tm , is used (radiography, medicine; its application for radiodiagnosis offers much promise for ^{170}Tm sources which are portable and do not require any special equipment and can successfully be used in place of expensive and cumbersome X-ray units).

tin [Anglo-Saxon origin] Sn. A Group IV element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 50, atomic mass 118.69, known to the ancients.

Properties: a silvery white bright metal, ductile, slowly tarnishes in the air because of the formation of a tin oxide film; changes to the brittle grey form at temperatures below 13.2°C , which may cause the destruction of things made of tin. The oxidation states in compounds are +4 (the stablest state) and +2. Rather unreactive under usual conditions, slowly dissolves in dilute acids and alkalis. The dissolution of tin in concentrated alkalis

yields salts of stannous acid, H_2SnO_3 , metal stannites; in the presence of oxidizing agents, salts of meta-stannic acid, H_2SnO_4 (stannates) are formed.

Occurrence: the chief ore is cassiterite (tinstone), SnO_2 .

Uses: 40% of commercial tin is used in the manufacture of tinplate; other uses are Babbitt metal, type metal, solders, and low-melting alloys. Stannous chloride, $SnCl_2$, is used as a reducing agent; stannic sulphide, SnS_2 (artificial or mosaic gold) as a goldish yellow pigment.

tin foil. Thin sheets of tin.

titanium [Gk *Titan*, a giant deity] Ti. A Group IV element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 22, atomic mass 47.90. Discovered by Gregor in 1789; pure metal was only prepared in 1925. Properties: a high-melting white metal, the oxidation states in compounds are +4, +3, less frequently +2; titanium dihalides are unstable substances. The reactivity of titanium increases with temperature. Highly resistant to corrosion because of the formation of a strong oxide film. Hydrochloric acid, especially hot acid, reacts with titanium; the metal is easily attacked by hydrofluoric acid.

Occurrence: rutile, TiO_2 ; ilmenite, $FeTiO_3$; some other minerals.

Derivation: by reducing titanium oxide with calcium metal or calcium hydride; by reducing titanate chloride with molten sodium or magnesium metal.

Uses: mostly as alloys with aluminium, molybdenum, vanadium, manganese, and other metals. A promising structural material for aircraft, chemical equipment, and shipbuilding. The advantage of titanium alloys is their high refractoriness compared with aluminium and magnesium alloys which is important for modern aviation.

titrated solution. A solution of known concentration used in titration.

titration. A gradual addition of a solution of known concentration from a burette to the solution to be analysed until the equivalence point is attained.

titre. The concentration of a dissolved substance in grams per 1 ml of the solution; e.g. a solution containing 0.001 g of solute per 1 ml of solution is said to have a titre of 0.001.

titrimetric analysis. A group of methods for quantitative determination of substances by measuring the volume of a standard solution used up in a reaction with the substance to be determined; utilizes reactions of various types (neutralization, redox reactions, precipitation, complex formation). The end point is usually detected with the help of indicators or by instrumental methods.

toluene (methylbenzene) $C_6H_5-CH_3$. An analogue of benzene, a colourless mobile liquid with a characteristic odour. Most its reactions are substitution reactions. Obtained from the products of coking of bituminous coal (from coal tar). Used in the manufacture of caprolactam, explosives (trinitrotoluene), benzoic acid, saccharin, aniline dyes, and as a solvent.

tombac. A copper-zinc alloy containing 88 to 97% copper. Easy to weld with steel and used to prepare steel-brass bimetal. Has a goldish colour; employed for decorative purposes, as a material for insignia and furniture.

topaz. A silicate mineral. Depending on the admixtures can be colourless (transparent), yellow, blue, violet, green, or pink. Used in glass manufacture, in electric furnaces for smelting steel, in the manufacture of refractory porcelain, and other refractories and ceramic materials. Also used as an abrasive (hardness 8). Transparent beautifully coloured specimens are used as gem stones from ancient times.

topochemical reaction. A reaction occurring in the solid phase at the solid starting material—solid reaction product interface (e.g. dehydration of hydrated salts, oxidation of metals). The most important topochemical reactions are calcination, reduction, chlorination of ores of heavy and nonferrous metals, the preparation of catalysts, the manufacture of ferrites, cementation of steel, the manufacture of ceramics, refractories, etc.

tourmaline. A borosilicate of aluminium. Colour variable depending on the chemical composition: black (schorlite), dark green (Brazilian emerald), dark-blue (indicolite), dark-red (rubellite). Tourmaline crystals are pyroelectric and piezoelectric materials (heating, pressure, friction induce charges of opposite signs on two sides of a tourmaline crystal). Large tourmaline crystals are used in electronics.

trace. A very small (10^{-6} to 10^{-9} g) admixture in a substance. Modern technology (the manufacture of nuclear fuels, special structural materials, refractory alloys, pharmaceuticals, semiconductors) imposes severe requirements on the purity of substances and elements. Thus in germanium used in semiconductors, not more than one impurity atom can be present per 10 milliard Ge atoms; semiconducting silicon should be still purer. The manufacture of pure and ultrapure materials depends on the development of the analytical procedures for the determination of traces of admixtures.

tracer. An isotopic form of an element that differs from the natural mixture of isotopes in its atomic mass or radioactivity. Tracers are added to a substance containing a given element; the behaviour of a tracer characterizes the behaviour of the element in a given process. Both stable and radioactive isotopes are used as tracers. Radioactive isotopes are registered using counters, ionizing chambers; stable isotopes are detected mass-spectrometrically. Tracers are used in chemistry, biology, medicine, and metallurgy. They are highly useful in obtaining information about transformations of elements in nature, metabolic processes, chemical and industrial processes.

transuranic elements. Radioactive chemical elements following uranium in the Mendeleev Periodic Table of Elements, atomic numbers ≥ 93 . Most transuranic elements known (atomic numbers 93 to 103) are actinides, all their isotopes have lifetimes below earth's age and therefore practically do not occur in nature and must be isolated in various nuclear reactions. The first transuranic element neptunium, Np (atomic number 93), was prepared in 1940 by bombarding uranium with neutrons. Then followed the discoveries of plutonium (Pu, at.no. 94), americium (Am, at.no. 95), curium (Cm, at.no. 96), berkelium (Bk, at.no. 97), californium (Cf, at.no. 98), einsteinium (Es, at.no. 99), fermium (Fm., at.no. 100), mendelevium (Md, at.no. 101), nobelium (No, at.no. 102), lawrencium (Lr, at.no. 103), and kurchatovium (Ku, at.no. 104). The elements with the atomic numbers of 105 and 106 were also synthesized. The chemical properties of transuranic elements were studied in more or less detail. The crystallographic studies and the stud-

ies of the absorption spectra of metal salts, the magnetic properties of metal ions, and other properties showed the elements with the atomic numbers of 93 to 103 to be lanthanide analogues. The most practically important transuranic element is ^{239}Pu (a nuclear fuel).

triple bond. A bond between two atoms formed by three electron pairs, viz. the $\text{C}\equiv\text{C}$, $\text{C}\equiv\text{N}$, and $\text{N}\equiv\text{N}$ bonds. The chemical behaviour of the $\text{C}\equiv\text{C}$ and $\text{C}\equiv\text{N}$ bonds is in a degree similar to that of the corresponding double bonds (they add halogens and hydrogen, are oxidizable, participate in the polymerization reactions, etc.).

tritium. A radioactive isotope of hydrogen with the mass number equal to 3; its nucleus consists of one proton and two neutrons (symbol T or ^3H). Half-life ($T_{1/2}$) 12 years, decays with the emission of beta particles. Small amounts of tritium are formed in nuclear processes. Manufactured by bombardment of lithium with slow neutrons. Tritium oxide is made by the oxidation of tritium in electric discharge. Because of the difference in masses reactions involving tritium differ in their rates from those of ordinary hydrogen. Tritium is used as a thermonuclear fuel in hydrogen bombs and nuclear energy devices. It is also used as a tracer in chemical, biological, etc. studies, to determine the origin of rains, the age of a wine or a meteorite, etc.

triton. The nucleus of tritium, symbol ^3H , contains one proton and two neutrons, mass 3.01646. Used as bombarding particle in cyclotrons.

tungsten [Sw. *tung*, heavy + *sten*, stone, also called wolfram] W. A Group VI element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 74, atomic mass 183.85. Discovered by Scheele in 1781, first isolated by Spaniards d'Elhujar brothers.

Properties: a white-grey metal, m.p. 3410°C , chemically stable under usual conditions. At elevated temperatures reacts with oxygen, carbon, and other elements. Reacts with fluorine at $+20^\circ\text{C}$, with other halogens at higher temperatures. Unattacked by acids except for hydrofluoric and nitric acids. The oxidation states in compounds are +4, +5, and, most often, +6.

Occurrence: in the minerals wolframite, $(\text{Fe}, \text{Mn})\text{WO}_4$, and scheelite, CaWO_4 ; as admixture to tin, molybdenum, and titanium ores.

Uses: alloying of steel, the manufacture of hard alloys, filaments of incandescent lamps, heating elements in electric furnaces, electrodes for welding, cathodes for vacuum-tube oscillators, high-voltage rectifiers, etc.

turbidimetry. The determination of the concentration of a substance from the absorption of light by suspended particles.

Turnbull's blue. See *Berlin blue*.

turpentine, spirits of. A complex mixture containing terpene hydrocarbons, $C_{10}H_{16}$, as the major components, a transparent volatile liquid with a smell of coniferous trees. Insoluble in water, very soluble in organic solvents, m.p. in the range of 150 to 220 °C. Made from wood containing oleoresin by distillation or extraction; used for dissolving lacquers, dyes, and enamels, and as a raw material for the manufacture of synthetic camphor, thymol, terpinol hydrate, lubricants, pesticides, and perfumes. Also used in medicine and household.

turquoise [Old French *turqueis*, Turkish, so named because brought to Western Europe through Turkey]. A natural basic hydrated phosphate of aluminium and copper, $CuAl_6[PO_4]_4(OH)_8 \cdot 4H_2O$. Colour blue or blue-green, hardness 5 to 6. Used as gem stone.

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ultramarine blue. A blue pigment, the product of the addition of sodium polysulphide, Na_2S_3 , to sodium aluminium silicate, $Na_2Al_2Si_2O_3$. Made by heating a mixture of kaolin, sulphur, and soda with a small admixture of sugar.

ultramicroanalysis. A combination of analytical techniques for the determination of very small, 10^{-6} to 10^{-12} g or 10^{-8} to 10^{-6} ml, amounts of substances. Employed in the study of biological objects such as cells, in the analysis of minerals and meteorites, alloys, new chemical elements such as actinides, etc. All the operations are carried out on a microscope stage.

unified atomic mass unit. Defined as $1/12$ of the mass of an atom of $^{12}_6C$, approximately equal to $(1.66043 \pm \pm 0.00031) \times 10^{-24}$ g.

unsaturated hydrocarbon. An open-chain hydrocarbon containing double and/or triple bond(s) between carbon atoms; can participate in addition reactions with its multiple bonds. For example, unsaturated hydrocarbons add bromine, readily undergo oxidation under the action of potassium permanganate. Many of them are capable of polymerization. Include several homologous series (the ethylene, acetylene series, etc.).

uranium [after Uranus, the planet] U. A Group III element of the 7th period of the Mendeleev Periodic Table of Elements, a radioactive element of the actinide series, atomic number 92, atomic mass 238.03. Natural uranium contains three isotopes, ^{238}U (99%), ^{235}U , and ^{234}U . None of them is stable. The ^{238}U and ^{235}U isotopes are parent isotopes of two natural radioactive series; the final products of their decay are helium and the stable ^{206}Pb and ^{207}Pb isotopes, respectively. The accumulation of the lead isotopes in specimens containing uranium (rocks, minerals, meteorites, etc.) can be used to determine the age of geological or cosmic objects. Discovered by Klaproth in 1789.

Properties: a silvery chemically active metal, the oxidation states in compounds are +6 and +4. Slowly undergoes oxidation in the air to form the oxides UO_2 , U_3O_8 , and UO_3 . Gives alloys with a number of metals.

Occurrence: the chief ore is pitchblende, U_3O_8 ; found in natural waters, in soil.

Derivation: by the reduction of UF_4 with calcium or magnesium metals at elevated temperatures.

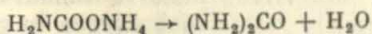
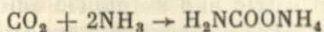
Uses: a fissionable material (fission is induced by the capture of neutrons) used as nuclear fuel and atomic bomb explosive. Uranium salts are used in photography, in glass manufacture, and in the analytical chemistry.

uranyl UO_2^{2+} . A positive doubly charged U(VI) ion, plays the part of a metal ion in a number of uranium compounds, e.g. uranyl nitrate, $\text{UO}_2(\text{NO}_3)_2$. Most uranium salts are green-yellow substances soluble in water.

urea (carbamide) $(\text{NH}_2)_2\text{CO}$. The final product of protein metabolism in man and mammals. Discovered in 1773.

Properties: a colourless and odourless crystalline substance, very soluble in water. Undergoes hydrolysis when heated together with solutions of alkalis or acids to give ammonia and carbonic acid.

Derivation: in industry is isolated from the reactions



Uses: a valuable nitrogen fertilizer (contains 47% available nitrogen), a starting material for the manufacture of plastics (urea-formaldehyde resins), sleeping-draughts, urotropin. See *methenamine*.

V

valence [L *valere*, to be strong]. The capability of atoms of an element to form chemical bonds with atoms of other elements, the possibility for an atom to give or take a definite number of electrons. In ionic compounds, valence is determined by the number of accepted or lost electrons; in covalent compounds, by the number of shared electron pairs formed in the combination of atoms. At present it is difficult to suggest a measure of the combining power of an atom. We can only mention such quantitative characteristics as valence (covalency), oxidation state, and coordination number.

valeric acid (pentanoic acid*) $\text{C}_5\text{H}_{10}\text{O}_2$. Any of monobasic saturated carboxylic acids of the composition indicated. Colourless liquids with a disagreeable odour. The most important isomer is isovaleric acid (β -methylbutyric acid), $(\text{CH}_3)_2\text{CHCH}_2\text{COOH}$, obtained by distillation from valerian, or synthetically. Used in the synthesis of pharmaceuticals such as methyl valerate (validol), bromisoval, etc. Isoamyl isovalerate (apple essence) is used in the food industry.

validol. See *methyl valerate*.

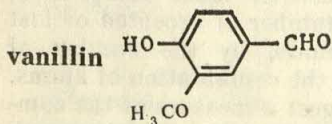
vanadium [Old Norse *Vanadis*, one of the names of the goddess Freya] V. A Group V element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 23, atomic mass 50.942, two stable isotopes, ^{51}V (99.75%) and ^{50}V (0.25%). First found by the Mexican mineralogist del Rio who took it to be chromium. Discovered by Sefstrom in 1831.

Properties: silvery grey metal, paramagnetic, m.p. 1900 °C. Unattacked by dilute solutions of nitric and

sulphuric acids and alkalis in the cold; hydrofluoric acid and concentrated nitric and sulphuric acids, and a mixture of HCl and HNO₃ dissolve vanadium. At 600 to 700 °C, vigorously reacts with oxygen to give vanadium oxide, V₂O₅. Forms compounds in the oxidation states +2, +3, +4, +5. The most important vanadium oxide is V₂O₅ which is used as catalyst in the contact process for the production of sulphuric acid and in the organic synthesis. Vanadium(V) oxide has an acidic character, it readily dissolves in alkalis to form metal vanadates, salts of vanadic acid.

Uses: alloying of steel, a constituent of alloys for permanent magnets; vanadium steels have increased hardness and high resistance to abrasion.

van der Waals forces. Forces of intermolecular interactions of 0.8 to 8.16 kJ/mole energy.



Properties: colourless crystals (needles) with vanilla aroma, m.p. 81-83 °C.

Derivation: contained in the form of glucoside in vanilla beans; also obtained synthetically.

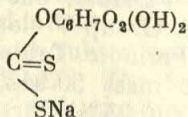
Uses: the manufacture of perfumes, in the food industry, pharmaceuticals.

vaseline. See *petroleum jelly*.

vinyl, an ethylene radical, CH₂=CH—.

vinyl chloride CH₂=CHCl. The product of the interaction of acetylene and hydrogen chloride. Readily undergoes polymerization to give polyvinyl chloride resins used in the manufacture of plastics.

viscose, a concentrated solution of cellulose xanthate,



in dilute aqueous NaOH. Used for making viscose rayon, nonfiber viscose products, synthetic leather.

viscosimetry. A combination of techniques for measuring viscosity.

vitamins [L *vita*, life]. A group of low-molecular weight organic substances of various structures essential to man and animals in small amounts. Vitamins are formed in organisms and participate in metabolism. The absence of any of the vitamins in the diet causes a disease (avitaminosis), excess vitamins result in hypervitaminosis. More than 20 vitamins are known. Subdivided into water- and fat-soluble species.

vitriol. A term used with reference to hydrated sulphates of certain heavy metals; the most important ones are green (iron) vitriol, $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$; blue vitriol or copper sulphate, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$; white (zinc) vitriol, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$.

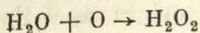
vivianite, blue iron bog ore, ferrous phosphate, $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$. Found in lowland, in marshy ground. Undergoes oxidation in the air.

vulcanization, process of combining rubber with sulphur to improve its useful properties.

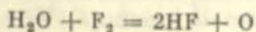
W

water (hydrogen oxide) H_2O . A compound of hydrogen and oxygen. Contains 88.8% oxygen and 11.2% hydrogen. The composition of water was determined by Lavoisier who synthesized it from hydrogen and oxygen.

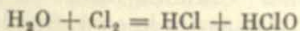
Properties: a colourless, tasteless, and odourless liquid, shows a number of anomalous physical properties. Electrical conductivity of pure water is explained by its dissociation to H^+ and OH^- . Liquid water, water vapour, and ice are in equilibrium with each other at 6×10^2 Pa and 0.0100°C . The dissolution of substances in water is accompanied by the hydrolysis and hydration processes. Of inorganic substances, many salts, acids, and alkalis are soluble in water; their aqueous solutions are electrolytes. Acid and basic oxides form acids and bases, respectively, upon the dissolution. Of organic substances, some alcohols, amines, carboxylic acids, sugars, etc. are soluble. Water participates in various reactions. It is oxidized by atomic oxygen to give hydrogen peroxide:



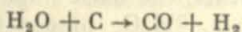
Water reacts with fluorine at room temperature to release atomic oxygen:



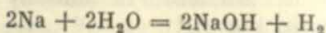
The dissolution of chlorine in water results in the formation of two acids:



The passage of water through glowing carbon yields a mixture of CO and H₂ (water gas)



Alkali and alkaline earth metals react with water at ambient temperature:

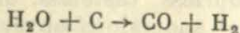


Water reacts with many metals at elevated temperatures. Many reactions occur only in the presence of water as catalyst (the reaction of alkali metals with Cl₂, of H₂ and Cl₂, etc.).

Occurrence: the most abundant compound on earth; forms hydrosphere, widely distributed in minerals and rocks, in plants and animals.

Uses: widely used for industrial purposes; drinking water is subjected to thorough purification.

water gas. A gas mixture containing 83 to 86% CO + H₂, made by the passage of water vapour through glowing carbon:



Used for the synthesis of various chemical products.
water, heavy, D₂O. A variety of water with hydrogen replaced by its heavier isotope, *deuterium*, D. First prepared in 1933. Found in natural water and fall-out. Differs from ordinary water in its physical properties (its density is larger by 10.77%, viscosity by 23.2%, etc.). Most compounds show far lower solubilities in heavy water than in ordinary one. Used as moderator of neutrons in nuclear reactors and for other purposes.

wax. Any of esters of the higher carboxylic acids and the higher monohydric alcohols, found in plants and animals. Very stable, insoluble in water, very soluble in gasoline, chloroform, and ether. Waxes are usually grouped according to their origin as follows: (i) animal: bees-

wax produced by bees; lanolin or wool fat, protects hide of animals from moisture, dirt, and drying; spermaceti, found in sperm-whale; (ii) vegetable, form thin layer coatings on leaves, stems, fruits to protect them from wetting, drying, injurious microorganisms; (iii) mineral, ozocerite, mainly consists of saturated hydrocarbons.

white spirit. A mixture of liquid hydrocarbons boiling in the range of 165 to 200 °C, obtained by distillation of petroleum. Mainly used as a solvent for lacquers and dyes.

wood alcohol. See *methanol*.

Wood's metal. A low-melting alloy, contains 50% Bi, 25% Pb, 12.5% Sn, and 12.5% Cd, m.p. 68 °C. Used in the preparation of models, microsections, as a solder, etc.

X

xenon [Gk *xenos*, strange] Xe. A Group VIII element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 54, atomic mass 131.30. Discovered in 1898 by Ramsay and Travers. Although it belongs with inert gases it forms a number of compounds, e.g. XeF_2 , XeF_4 , XeF_6 , XeO_4 , $\text{Xe} \cdot 6\text{H}_2\text{O}$. Isolated from the air. Used in electrovacuum technique and for filling vacuum tubes.

xylene. Any of dimethylbenzenes (*ortho*-, *meta*-, or *para*-), $\text{C}_6\text{H}_4(\text{CH}_3)_2$. All xylenes are colourless liquids, with a characteristic odour, very soluble in organic solvents. A typical aromatic hydrocarbon, readily undergoes chlorination, sulphonation, and nitration. Obtained in coking carbon and aromatizing petroleum. Used as a solvent for lacquers, dyes, mastics, etc. and in the manufacture of dyes.

Y

yperite. See *mustard gas*.

ytterbium [from Ytterby, a town in Sweden] Yb. A Group III element of the 6th period of the Mendeleev Periodic Table of Elements, atomic number 70, atomic mass

173.04, a lanthanide. Separated by Marignac in 1878. The oxidation states in compounds +2, +3.

yttrium [from Ytterby, a town in Sweden] Y. A Group III element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 39, atomic mass 88.905. The rare earth yttria which contained a new element was discovered by Gadolin in 1794. Afterwards yttrium oxide and a number of lanthanide oxides were isolated from that mineral. Yttrium metal was first obtained by Wöhler in 1828.

Properties: free yttrium is a soft metal analogous to lanthanides in its chemical properties. The oxidation state in compounds +3. Slowly reacts with boiling water, readily dissolves in acids, reacts with halogens and hydrogen.

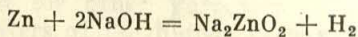
Occurrence: found together with rare earth elements.

Uses: nuclear engineering, aircraft. Yttrium oxide, Y_2O_3 , is used in the manufacture of yttrium ferrites for electronics, computers, etc.

Z

zeolite. A general term for a group of naturally occurring hydrated aluminosilicates of either sodium or calcium or both. Minerals with vitreous or pearly lustre. Can absorb and desorb water depending on the temperature and humidity; can also be used as ion exchangers. In industry, artificial zeolites (Permutits) are mostly used.

zinc [Gk *zink*, zinc] Zn. A Group II element of the 4th period of the Mendeleev Periodic Table of Elements, atomic number 30, atomic mass 65.37. Known to the ancients. Properties: a greyish-white metal, forms a strong protective film when exposed to the air. The oxidation state in compounds +2. Dissolves in acids and alkalis with the evolution of hydrogen. With alkalis, forms zincates:



At present, metal zincates of the compositions $Na[Zn(OH)_3]$, $Na_2[Zn(OH)_4]$ have been isolated. Zinc hydroxide, $Zn(OH)_2$, shows amphoteric properties, it dissolves in both acids and alkalis, and also in aqueous

ammonia with the formation of the complex $[\text{Zn}(\text{NH}_3)_4]^{2+}$ ion. Zinc is a strong reducing agent, easily displaces other metals such as Cu or Fe from solutions of their salts. Occurrence: the chief ore is sphalerite (zinc blende), ZnS.

Uses: galvanizing iron and steel to protect them from corrosion, alloys with copper (brass), galvanic cells, etc. See *zinc compounds*.

zinc compounds. Zinc oxide ZnO is a loose white powder used in the manufacture of zinc white which does not darken on exposure to the air and is not toxic (cf. lead white); also used as a filler in rubber and plastics, in medicine, cosmetics. Zinc chloride ZnCl_2 is a deliquescent substance used for impregnating sleepers (a wood preservative), etching metals, as a dehydrating agent. Zinc sulphate or zinc vitriol, $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, is used in viscose manufacture, as a microfertilizer for grass, in the manufacture of dyes, in medicine. Zinc sulphide ZnS occurring in nature as mineral sphalerite (zinc blende) is extensively used as a phosphor, in the manufacture of dyes (ingredient of lithopone).

zinc plating (galvanizing). A coating of steel and pig iron articles with a zinc layer to prevent corrosion.

Zinin's reaction. A reaction for the preparation of aromatic amines by reducing aromatic nitrocompounds: $\text{C}_6\text{H}_5\text{NO}_2 + 3\text{H}_2\text{S} = \text{C}_6\text{H}_5\text{NH}_2 + 3\text{S} + 2\text{H}_2\text{O}$. This reaction was used in the first syntheses of aniline and 1-naphthylamine. Discovered in 1842 by Zinin.

zircon. A natural zirconium orthosilicate, ZrSiO_4 . Contains hafnium, may contain yttrium, cerium, thorium, and uranium. An ore of zirconium. Used in the manufacture of refractories (bricks and cement). Added to quartz glass (up to 2.4%) for the manufacture of chemical glass ware resistant to heating and action of acids. Employed as inert substance in high-temperature experiments and in aggressive media. Transparent red and brown zircon crystals (hyacinth or jacinth) are used as gem stones.

zirconium [Per *zargun*, gold-coloured] Zr. A Group IV element of the 5th period of the Mendeleev Periodic Table of Elements, atomic number 40, atomic mass 91.22. Discovered in 1789 by Klaproth.

Properties: a silvery white metal, very ductile and malleable in the pure state. The oxidation states in compounds

+2 and +4. Shows low reactivity under usual conditions. Occurrence: the chief ore is zircon, ZrSiO_4 .

Uses: zirconium and its alloys are used as structural materials in nuclear engineering; zirconium is also used as gas absorber in electrovacuum technology, as alloying element in metallurgy, etc. Zirconium oxide, ZrO_2 , and zircon are employed as refractories.

zone refining. One of the methods of purification of substances. Based on different solubilities of admixtures in the liquid and solid phases of the material undergoing refinement. The process is carried out by slowly moving a crucible of a special shape through a furnace; a very small portion (zone) of a metal ingot within the furnace is molten, and that portion moves from one end of the ingot to the other one as the crucible continues its motion. The admixtures are accumulated in the molten portion and move together with it to be concentrated in one end of the ingot after the process has been completed. The method is employed to refine germanium, silicon, tin, aluminium, bismuth, and gallium.

APPENDIX

The History of the Discovery of the Chemical Elements

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
1	H hydrogen	1766	Cavendish (England)	Boyle (1666) and Lomonosov (1745) also observed the evolution of hydrogen. Like Lomonosov, Cavendish thought hydrogen to be phlogiston
2	He helium	1868	Janssen (France) Lockyer (England)	On earth helium was first detected by Ramsay and Crookes (England) in cleveite (a variety of uraninite)
3	Li lithium	1817	Arfvedson (Sweden)	Isolated from petalite in the form of lithium oxide; lithium metal was first prepared by Davy (England) in 1818
4	Be beryllium	1798	Vauquelin (France)	Isolated in the form of beryllium oxide from beryl and emerald; prepared in the free state by Wöhler and by Bussy (Germany) independently in 1828
5	B boron	1808	Davy (England) Gay-Lussac and Thénard (France)	Isolated in free state from the oxide; natural boron compounds have been known from the Middle Ages
6	C carbon	known from ancient times		Was shown to be an element by Lavoisier (France) in 1787

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
7	N nitrogen	1772	Rutherford (England)	Nitrogen as air constituent was identified almost simultaneously by Cavendish, Priestley (England), and Scheele (Sweden)
8	O oxygen	1774	Scheele (Sweden)	The chemical nature of oxygen was established by Lavoisier (France)
9	F fluorine	1771	Priestley (England) Scheele (Sweden)	Isolated in the form of hydrofluoric acid, HF, whose composition was determined by Ampere (France) in 1810; first isolated in the free state by Moissan (France) in 1886
10	Ne neon	1898	Ramsay and Travers (England)	The existence of a light rare gas was predicted by Ramsay and other scientists
11	Na sodium	1807	Davy (England)	Sodium compounds have been known from ancient times
12	Mg magnesium	1808	Davy (England)	Magnesium compounds have been known from ancient times
13	Al aluminium	1825	Oersted (Denmark)	Aluminium compounds have been known from ancient times
14	Si silicon	1823	Berzelius (Sweden)	Known in compounds from ancient times; Berzelius prepared amorphous silicon, Sainte-Claire Deville obtained it in the crystalline state (France, 1855)
15	P phosphorus	1669	Brand (Germany)	The date is only conjectural; there is evidence that phosphorus was prepared as early as the 12th century
16	S sulphur	known to the ancients		Found native as brimstone
17	Cl chlorine	1774	Scheele (Sweden)	Chlorine compounds have been known from ancient times; was shown to be an element by Davy (England) in 1810

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
18	Ar argon	1894	Rayleigh and Ramsay (England)	First detected in earth's atmosphere together with other rare gases; isolated in the pure form in 1898
19	K potassium	1807	Davy (England)	Potassium compounds have been known from ancient times
20	Ca calcium	1808	Davy (England)	Calcium compounds have been known from ancient times
21	Sc scandium	1879	Nilson (Sweden)	Predicted by Mendeleev as eka-boron; isolated during resolving ytterbia into its components (see below). In the free state prepared by Fischer and co-workers (Germany) in 1936
22	Ti titanium	1795	Klaproth (Germany)	Isolated from rutile in the form of the oxide, prepared in the free state by Berzelius (Sweden) in 1825. Was, probably, first isolated by Gregor (England) in 1791
23	V vanadium	1830	Sefstrom (Sweden)	Isolated in the form of the oxide as an admixture in pig iron; vanadium metal was prepared by Roscoe (England) in 1869. Vanadium compounds were first described by del Rio (Mexico) who, however, failed to recognize vanadium to be an element
24	Cr chromium	1797	Vauquelin (France)	Isolated in the free state from the mineral crocoite
25	Mn manganese	1774	Scheele and Gahn (Sweden)	Isolated in the free state from the mineral pyrolusite

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
26	Fe iron	known to the ancients		Probably, first found in meteorites
27	Co cobalt	1735	Brandt (Sweden)	Was, probably, known in the Middle Ages. Brandt isolated a mixture of cobalt oxide and cobalt metal; pure metal was prepared by Berzelius (Sweden) in 1808
28	Ni nickel	1751	Cronstedt (Sweden)	Nickel metal was prepared from a sulphide ore
29	Cu copper	known from prehistoric times		Found as native copper
30	Zn zinc	known in the form of brass from ancient times		Zinc metal was probably first obtained in the 12th century
31	Ga gallium	1875	Lecoq de Boisboudran (France)	Predicted by Mendeleev as eka-aluminium. Discovered by the spectral method in zinc blende and isolated in the free state
32	Ge germanium	1886	Winkler (Germany)	Predicted by Mendeleev as eka-silicon. Isolated as free metal from the mineral argyrodite
33	As arsenic	arsenic compounds have been known from ancient times		Arsenic element was, probably, prepared by alchemist Albertus Magnus (the 13th century)
34	Se selenium	1817	Berzelius and Gahn (Sweden)	Isolated in the free state from the residue of sulphuric acid manufacture
35	Br bromine	1826	Balard (France)	Isolated from ashes of seaweeds. In 1825, extracted from mineral waters by Löwig (Germany)

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
36	Kr krypton	1898	Ramsay and Travers (England)	Detected in the atmosphere
37	Rb rubidium	1861	Bunsen and Kirchhoff (Germany)	Detected spectroscopically in the mineral lepidolite; rubidium metal was isolated by Bunsen (Germany) in 1863
38	Sr strontium	1787	Crawford (England)	Isolated in the form of strontium oxide from the mineral strontianite. Strontium metal was prepared by Davy (England) in 1808
39	Y yttrium	1794	Gadolin (Finland)	First the rare earth yttria was isolated from gadolinite; it was then resolved into individual oxides of the rare earth elements of the yttrium subgroup. Yttrium metal was prepared by Wöhler (Germany) in 1828
40	Zr zirconium	1739	Klaproth (Germany)	Isolated as zirconium oxide from the mineral zircon; prepared by Berzelius (Sweden) in the free state in 1824
41	Nb niobium	1801	Hatchett (England)	Isolated as niobium oxide from the mineral columbite; the product might, however, also be tantalum oxide (see below). The existence of niobium was proved by Rose in 1844. The metal was prepared by Bolton (USA) in 1907
42	Mo molybdenum	1778	Scheele (Sweden)	Prepared in the form of the oxide from molybdenite (molybdenum glance); molybdenum metal was obtained by Berzelius (Sweden) in 1817
43	Tc technetium	1937	Perrier and Segré (Italy)	Synthesized by the nuclear reaction $\text{Mo}(d, n)\text{Tc}$, produced in weighable amount in 1945. Technetium metal was prepared in 1961. Found in nature by Kenna and Kuroda (USA) in 1961

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
44	Ru ruthenium	1844	Klaus (Russia)	Isolated in the form of ruthenium sulphide from a platinum ore after the extraction of platinum; first obtained in the pure state by Klaus (Russia)
45	Rh rhodium	1803	Wollaston (England)	Rhodium metal was prepared during processing of crude platinum
46	Pd palladium	1803	Wollaston (England)	Palladium metal was prepared during processing of crude platinum
47	Ag silver	known from ancient times		Found in the form of native silver
48	Cd cadmium	1817	Stromeyer (Germany)	Cadmium metal was prepared from an impurity in zinc oxide
49	In indium	1863	Reich and Richter (Germany)	Discovered by a spectroscopic technique in zinc blende and isolated in the form of indium metal
50	Sn tin	known from ancient times		Bronze, an alloy of tin and copper, was produced as early as three thousand years B.C.
51	Sb antimony	known from ancient times		There is evidence that antimony was used by the ancients
52	Te tellurium	1782	Muller von Richenstein (Hungary)	Isolated in the pure state from auriferous rocks
53	I iodine	1811	Courtois (France)	Isolated in the pure state from products of leaching of seaweeds
54	Xe xenon	1898	Ramsay, Travers (England)	Detected in the atmosphere
55	Cs cesium	1860	Bunsen and Kirchhoff (Germany)	Detected spectroscopically in mineral waters. The free metal was prepared by Setterberg (Sweden) in 1882

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
56	Ba barium	1774	Scheele and Gahn (Sweden)	Isolated in the form of barium oxide; barium metal was prepared by Davy (England) in 1808
57	La lanthanum	1839	Mosander (Sweden)	Detected as lanthanum oxide in ceria prepared from cerite. Lanthanum metal was obtained by Hillebrand and Norton (Germany) in 1875
58	Ce cerium	1803	Berzelium and Hisinger (Sweden) Klaproth (Germany)	The oxide discovered was a mixture of rare earths of the cerium subgroup. Mosander (Sweden) separated it into three components (1839), cerium, lanthanum, and didymium (didymium was later also shown to be a mixture). Cerium metal was prepared by Hillebrand and Norton (Germany) in 1875
59	Pr praseodymium	1885	Von Welsbach (Austria)	Praseodymium oxide was prepared by separating didymia; the metal was prepared by Muthmann and co-workers (Germany) in 1902
60	Nd neodymium	1885	Von Welsbach (Austria)	Neodymium oxide was prepared by separating didymia; the metal was prepared by Muthmann and co-workers (Germany) in 1902
61	Pm promethium	1945 (1947)	Marinsky, Glendinning, and Coryell (USA)	Isolated from the products of fission of uranium by thermal neutrons; in 1948, obtained in weighable amount by Parker and Lantz (USA). Promethium metal was prepared by Weigel (FRG) in 1963. Found in nature by Kuroda (USA) in 1968
62	Sm samarium	1879	Lecoq de Boisboudran (France)	The oxide isolated was a mixture of a number of rare earths; individual compound was obtained by Demarcay (France) in 1901. Samarium metal was prepared by Muthmann and co-workers (Germany) in 1902

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
63	Eu Europium	1896	Demarcay (France)	The presence of an unknown element in samarium was proved spectroscopically. Europium metal was prepared by Trombe (France) in 1938
64	Gd gadolinium	1886	Lecoq de Boisbaudran (France)	Gadolinium oxide was discovered in separating samaria. The metal was prepared by Trombe (France) in 1935
65	Tb terbium	1843	Mosander (Sweden)	Isolated as oxide in separating rare earths of the yttrium group. A conclusive evidence of the existence of terbium was obtained in 1878. Terbium metal was prepared by Daane and Spedding (USA) in 1953
66	Dy dysprosium	1886	Lecoq de Boisbaudran (France)	Discovered in the spectral study of holmium oxide. The metal was prepared by Trombe (France) in 1945
67	Ho holmium	1879	Cleve (Sweden)	A mixture of holmium and dysprosium oxides was isolated in separating erbia earth. Individual oxide was obtained in 1886, holmium metal was prepared by Daane and Spedding (USA) in 1953
68	Er erbium	1843	Mosander (Sweden)	Erbium oxide was isolated from yttria as a mixture of several rare earths. Pure oxide was obtained in 1879, erbium metal was prepared by Daane and Spedding (USA) in 1953
69	Tu thulium	1879	Cleve (Sweden)	Isolated from erbia earth as the oxide; thulium metal was prepared by Daane and Spedding (USA) in 1953
70	Yb ytterbium	1878	Marignac (Switzerland)	Isolated from erbia earth as a mixture of several rare earth metal oxides. Pure ytterbium oxide was obtained in 1907. The metal was prepared by Daane and Spedding (USA) in 1953

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
71	Lu lutetium	1907	Urban (France) von Welsbach (Austria)	Obtained in separating ytterbia earth. The metal was prepared by Spedding and Daane (USA) in 1954
72	Hf hafnium	1923	Coster and Hevesey (Denmark)	Discovered in the X-ray spectral study of zircon and isolated in the free state
73	Ta tantalum	1802	Ekeberg (Sweden)	Isolated in the form of the oxide from several minerals; tantalum and niobium were long thought to be one and the same element. A conclusive evidence of their being separate elements was obtained by Rose in 1844. The metal was prepared by Bolton (USA) in 1905
74	W tungsten	1781	Scheele (Sweden)	The oxide was isolated from the mineral later named scheelite. The metal was prepared by d'Elhujar brothers in 1783 (Sweden)
75	Re rhenium	1925	Noddack, Take, and Berg (Germany)	Discovered by the X-ray spectral method in the analysis of a number of minerals. A reliable proof of its existence was however obtained only in 1927. The metal was prepared by Noddack and Take in 1928
76	Os osmium	1804	Tennant (England)	Isolated in the form of an alloy with iridium from crude platinum
77	Ir iridium	1804	Tennant (England)	Isolated in the form of an alloy with osmium from crude platinum
78	Pt platinum	known from ancient times		The first detailed description of platinum was given by Ulloa (Spain) in 1748
79	Au gold	known from ancient times		
80	Hg mercury	known from ancient times		

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
81	Tl thallium	1861	Crookes (England)	Discovered by the spectral method in the residue left after tellurium had been extracted from its ore. The metal was prepared by Lamy (France) in 1861 who discovered thallium independently
82	Pb lead	known from ancient times		
83	Bi bismuth	has been known from the Middle Ages		
84	Po polonium	1898	P. and M. Curie (France)	Discovered by the radiometric method. Marckwald (Germany) showed it to be an analogue of tellurium (1902). The metal was prepared by Maxwell (USA) in 1946
85	At astatine	1940	Corson, MacKenzie, and Segré (USA)	Prepared by the reaction $^{209}\text{Bi}(\alpha, 2n)^{211}\text{At}$. Was not obtained in the free state. Found in nature by Karlik and Bernert (Austria) in 1943
86	Rn radon	1900	Dorn (Germany)	Thorium emanation (thoron, the isotope of radon) was observed by Rutherford and Owens (Canada) in 1899, radium emanation (radon) was discovered in 1900, and actinon (actinium emanation, one more isotope of radon) in 1902 by Debierne (France)
87	Fr francium	1939	Mlle. Perey (France)	Discovered by the radiometric method as the product of rare alpha decay of ^{237}Ac . Was not isolated in the free state. Synthesized in 1935

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
88	Ra radium	1898	M. and Mme Curie and Bémont (France)	Discovered by the radiometric method and identified chemically as an analogue of barium. The spectrum of radium was obtained by Demarcay (France); radium metal was prepared by Mme Curie and Debierne (France)
89	Ac actinium	1899	Debierne (France)	Debierne in fact observed emission from a complex mixture of active Ac precipitates; a more accurate description of the element was given by Giesel (Germany) in 1902. The metal was prepared by Farr et al. (USA) in 1953
90	Th thorium	1828	Berzelius (Sweden)	Thorium oxide was isolated from the mineral thorite. The metal was prepared by Nilsson (Sweden) in 1882
91	Pa protactinium	1918	Soddy and Cranston (England) Hahn and Meitner (Germany) Klaproth (Germany)	The date listed refers to the long-lived isotope, ^{231}Pa . The short-lived isotope, ^{234}Pa , was identified by Fajans and Göring (Germany) in 1913. The metal was prepared by Grosse (USA) in 1934
92	U uranium	1789		Discovered as oxide in pitchblende. The metal was prepared by Peligot (France) in 1841
93	Np neptunium	1940	McMillan and Abelson (USA)	Synthesized according to the nuclear reaction $^{238}\text{U} (n, \gamma) ^{239}\text{U} \xrightarrow{\beta} ^{239}\text{Np}$. The longest-lived isotope, ^{237}Np , was produced by Seaborg and Wahl (USA) in 1942. Occurs in nature (1952). The metal was prepared in 1944

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
94	Pu plutonium	1940	Seaborg, McMillan, Kennedy, and Wahl (USA)	Produced from natural uranium by the reaction: $^{238}\text{U} (d, 2n) ^{238}\text{Np} \xrightarrow{\beta} ^{238}\text{Pu}$. The longest-lived isotope, ^{244}Pu , was synthesized by Hess and co-workers (USA); the metal was prepared in 1942. Was shown to occur in nature (1951)
95	Am americium	1945	Seaborg, James, Morgan, and Ghiorso (USA)	Synthesized by the reaction $^{239}\text{Pu} (n, \gamma) ^{240}\text{Pu} (n, \gamma) ^{241}\text{Pu} \xrightarrow{\beta} ^{241}\text{Am}$. The longest-lived isotope, ^{243}Am , was produced by Street and co-workers (USA) in 1950. The metal was prepared in 1951
96	Cm curium	1944	Seaborg, James, and Ghiorso (USA)	Synthesized from plutonium, $^{239}\text{Pu} (\alpha, 2n) ^{242}\text{Cm}$. The longest-lived isotope, ^{247}Cm , was obtained by Fields and co-workers (USA) in 1956. The metal was prepared in 1964
97	Bk berkelium	1949	Thompson, Ghiorso, and Seaborg (USA)	Produced from americium-241: $^{241}\text{Am} (\alpha, 2n) ^{243}\text{Bk}$. The longest-lived isotope, ^{247}Bk , was synthesized by Chattan-Strode (USA) in 1956. The element was prepared in weighable amount in 1948, in the form of the metal in 1965
98	Cf californium	1949	Thompson, Street, Ghiorso, and Seaborg	Synthesized by the reaction $^{242}\text{Cm} (\alpha, 2n) ^{245}\text{Cf}$. The longest-lived isotope, ^{251}Cf , was prepared by Dimond (USA) in 1954. The metal was obtained in 1971

Z	Symbol and name	Generally accepted date of the discovery	Authors	Details
99	Es einsteinium	1952	Ghiorso and co-workers (USA)	Einsteinium-253 was identified in the debris from a thermonuclear explosion. The longest-lived isotope, ^{254}Es , was synthesized by Harvey and co-workers (USA) in 1955
100	Fm fermium	1953	Ghiorso and co-workers (USA)	Fermium-255 was discovered in the debris from the 1952 hydrogen bomb explosion; the longest-lived isotope, ^{257}Fm , was synthesized by Asaro and Perlman (USA) in 1967
101	Md mendelevium	1955	Ghiorso, Harvey, Choppin, Thompson, and Seaborg (USA)	Detected in the reaction $^{253}\text{Es}(\alpha, n)^{256}\text{Md}$. The longest-lived isotope, ^{258}Md , was synthesized by Fields and co-workers (USA) in 1957
102	no generally accepted name, known as nobelium, No	Isotopes of element-102 were reliably synthesized in 1963-1966	Flerov and co-workers (USSR)	All the isotopes were obtained in nuclear reactions involving heavy ions, e.g. $^{238}\text{U}(^{22}\text{Ne}, 5n)^{255}\text{102}$
103	Lw lawrencium	1961	Ghiorso and co-workers (USA)	A proved synthesis was performed by Flerov et al. in 1965: $^{243}\text{Am}(^{18}\text{O}, 5n)^{253}\text{103}$
104	Ku kurchatovium	1964	Flerov and co-workers (USSR)	Synthesized by the reaction $^{242}\text{Pu}(^{22}\text{Ne}, 4n)^{260}\text{Ku}$
105	Ns nielsbohrium	1970	Flerov and co-workers (USSR)	Synthesized by the reaction $^{243}\text{Am}(^{22}\text{Ne}, 4n)^{261}\text{Ns}$
106	has no name		Flerov, Oganesyan, and co-workers (USSR)	Synthesized by the reaction $^{208}\text{Pb}(^{54}\text{Cr}, 3n)^{259}\text{106}$
107	has no name		Flerov, Oganesyan, and co-workers (USSR)	Synthesized by the reaction $^{209}\text{Bi}(^{54}\text{Cr}, 2n)^{261}\text{107}$

Some of the Most Important Industrial Minerals

Metal	Mineral	Notes
Lithium	Spodumene $\text{LiAl}(\text{Si}_2\text{O}_6)$ Lepidolite $\text{KLi}_{1.5}\text{Al}_{1.5}[\text{Si}_3\text{AlO}_{10}\text{F}(\text{OH})]_2$	The percentage of lithium oxide in an ore should be not smaller than 0.7; world resources of lithium are about 5 million tons
Sodium	Halite NaCl Trona $\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$	
Potassium	Sylvite KCl Sylvinite $\text{KCl} \cdot \text{NaCl}$ Carnallite $\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ Kainite $\text{KCl} \cdot \text{MgSO}_4 \cdot 3\text{H}_2\text{O}$	
Cesium	Pollucite $2\text{Cs}_2\text{O} \cdot 2\text{Al}_2\text{O}_3 \cdot 9\text{SiO}_2 \cdot \text{H}_2\text{O}$	Ores of copper may contain lead, molybdenum, iron, vanadium, titanium, gold, silver, rhenium Content not less than 1 to 2 g per ton World resources of gold are about 20 thousand tons Accompanying elements: tin, tungsten, molybdenum, tantalum, lithium, niobium, etc.
Copper	Chalcopyrite CuFeS_2 Chalcocite Cu_2S Covellite Cu_2O Cuprite Native copper	
Gold	Native gold Calaverite AuTe_2 Sylvanite AuAgTe_4	
Beryllium	Beryl $\text{Be}_3\text{Al}_2(\text{Si}_6\text{O}_{18})$ Chrysoberyl BaAl_2O_4 Phenacite Be_2SiO_4	
Barium	Barite BaSO_4 Witherite BaCO_3	
Magnesium	Olivine Mg_2SiO_4 Serpentine $\text{H}_4\text{Mg}_3\text{Si}_2\text{O}_9$ Magnesite MgCO_3 Dolomite $\text{MgCa}(\text{CO}_3)_2$	Asbestos is a fibrous variety of magnesium silicates; Magnesium chloride occurring in sea and lake water is also used as a source of magnesium

Metal	Mineral	Notes
Calcium	Calcite CaCO_3 Aragonite CaCO_3 Chalk, marble, limestone CaCO_3 Anhydrite CaSO_4 Fluorite CaF_2 Apatite $\text{Ca}_5(\text{F}, \text{Cl}, \text{OH}) \cdot (\text{PO}_4)_3$	Trigonal crystals; Rhombic crystals; Calcium is also found in many other minerals
Strontium	Celestite SrSO_4	
Mercury	Strontianite SrCO_3 Cinnabar HgS Metacinnabarite HgS Native mercury Livingstonite HgSb_4S_7	World resources of mercury are about 1 million tons
Aluminium	Bauxite $\text{AlO}(\text{OH})$, a mixture of diasporite and boehmite Nephelite $(\text{Na}, \text{K})_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$ Alunite $(\text{Na}, \text{K})_2\text{SO}_4 \cdot \text{Al}_2(\text{SO}_4)_3 \cdot 4\text{Al}(\text{OH})_3$ Kaolinite $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ Various aluminium silicates	Ores of industrial importance are bauxite, alunite, and nephelite
Scandium	Found in ores of tin (cassite- rite), tungsten (wolframite), and in some other rare min- erals	Extracted from concentrates of ores of rare metals
Thallium	Found in galena, chalcopryrite, sphalerite, and other sulphide minerals	
Germanium	Argyrodite Ag_8GeS_4 Germanite CuGeS_4	Found in sphale- rite, magnetite, and some coals
Titanium	Rutile, anatase, brookite (va- rieties of TiO_2) Ilmenite FeTiO_3 Perovskite CaTiO_3 $(\text{Na}, \text{Cr}, \text{Ca}) (\text{Nb}, \text{Ti})\text{O}_3$ Titanite (sphene) $\text{CaO} \cdot \text{TiO}_2 \cdot \text{SiO}_2$ Titanomagnetites (mixtures of ilmenite and magnetite, Fe_3O_4)	The chief ores of industrial impor- tance are rutile, ilmenite, titanite, titanomagnetite
Tin	Cassiterite SnO_2 Stannite $\text{Cu}_2\text{FeSnS}_4$	

Metal	Mineral	Notes
Lead and zinc	Galena PbS Sphalerite ZnS Smithsonite ZnCO_3 Jamesonite $\text{Pb}_4\text{FeSb}_6\text{S}_{14}$ Cerussite PbCO_3 Anglesite PbSO_4	Hafnium is found as admixtures in ores of zirconium
Zirconium and hafnium	Zircon ZrSiO_4 Baddeleyite ZrO_2 Eudialite $(\text{Na}, \text{Ca})_6\text{Zr}(\text{Si}_6\text{O}_{18})(\text{OH}, \text{Cl})$	
Vanadium	Patronite VS_2 , V_2S_5 Vanadinite $\text{Pb}_5(\text{VO}_4)_3\text{Cl}$ Roscoelite $\text{KV}_2(\text{AlSi}_3\text{O}_{10})(\text{OH})_2$ Carnotite $\text{K}_2(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 3\text{H}_2\text{O}$	
Tantalum and niobium	Tantalite $(\text{Fe}, \text{Mn})(\text{Ta}, \text{Nb})_2\text{O}_6$ Columbite $(\text{Fe}, \text{Mn})(\text{Nb}, \text{Ta})_2\text{O}_6$	Accompanying elements: tin, zirconium, lithium, etc.; percentages of tantalum and niobium oxides not smaller than 0.2 and 0.1, respectively Chromite, a mineral of the spinel family, is the only ore of practical importance Accompanying elements: molybdenum, gold, copper, bismuth, tin, beryllium, lead, zinc, etc. Accompanying elements: gold, tungsten, beryllium, tin, rhenium, rare earth elements
Chromium	Chromite FeCr_2O_4 Crocoite PbCrO_4 Uvarovite $\text{Ca}_3\text{Cr}_2(\text{SiO}_4)_3$	
Tungsten	Wolframite $(\text{Fe}, \text{Mn})\text{WO}_4$ Scheelite CaWO_4 Hübnerite MnWO_4 Ferberite FeWO_4	
Molybdenum	Molybdenite MoS_2	
Uranium	Uraninite UO_2 Torbernite $\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 12\text{H}_2\text{O}$	

Metal	Mineral	Notes
Iron	Tyuyamunite $\text{Ca}(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 8\text{H}_2\text{O}$ Carnotite (see vanadium) Magnetite Fe_3O_4 Hematite Fe_2O_3 Siderite FeCO_3 Limonite $\text{Fe}_2\text{O}_3 \cdot \text{aq}$ Goethite HFeO_2	Accompanying elements: manganese, nickel, cobalt, molybdenum, titanium, germanium, vanadium; world resources of iron are about 75 milliard tons
Manganese	Pyrolusite MnO_2 Braunite Mn_2O_3 Hausmannite Mn_3O_4 Manganite $\text{MnO}_2 \cdot \text{Mn}(\text{OH})_2$ Psilomelane (colloidal oxides) $x\text{MnO} \cdot y\text{MnO}_2 \cdot z\text{H}_2\text{O}$ Rhodochrosite MnCO_3	Accompanying elements: iron, nickel, cobalt, etc.; world resources of manganese are above 1 milliard tons
	Rhodonite MnSiO_3	
	Pentlandite $(\text{Fe}, \text{Ni})_9\text{S}_8$	
	Millerite NiS	
	Niccolite NiAs	
	Gersdorffite NiAsS	
Nickel	Garnierite $\frac{7}{3}$	Accompanying elements: copper, cobalt, platinum, palladium, rhodium, gold, silver, selenium, tellurium; world resources of nickel are about 50 million tons
	Ni ₄ (Si ₄ O ₁₀)(OH) ₄ · 4H ₂ O	

Physical quantity	Name	Symbol	Definition
<i>Base SI units</i>			
length	metre	m	1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom
mass	kilogramme	kg	kilogramme (or kilogram) is represented by the international prototype kilogramme at the International Bureau of Weights and Measures at Sèvres in France
time	second	s	the duration of 9 192 631 770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the caesium-133 atom
electric current	ampere	A	that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed one metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length
thermodynamic temperature	kelvin	K	$1/273.16$ of the thermodynamic temperature of the triple point of water
amount of substance	mole	mol	the amount of substance of a system that contains as many elementary entities as there are atoms in 0.042 kg of carbon-12. The elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of particles
luminous intensity	candela	cd	the luminous intensity, in the perpendicular direction, of a surface of $1/600\,000$ square metre of a black body (full radiator) at the temperature of freezing platinum under a pressure of 101 325 newtons per metre squared

Physical quantity	Name	Symbol	Definition
<i>Supplementary units</i>			
plane angle	radian	rad	encloses an arc equal to the radius of a concentric circle
solid angle	steradian	sr	one steradian is subtended at the centre of a sphere of radius r by a portion of its surface of area r^2
<i>Derived SI Units</i>			
<i>Space and time units</i>			
area		m^2	the area of a square whose sides are one metre in length
volume		m^3	the volume of a cube whose edges are one metre in length
velocity		m/s	the velocity of a point involved in a rectilinear uniform motion and traversing one metre per one second
acceleration		m/s^2	the acceleration of a point involved in a rectilinear uniformly accelerated motion whose velocity increases by 1 m/s per one second
angular velocity		rad/s	the angular velocity of a uniformly rotating body which turns by one radian per one second
angular acceleration		rad/s^2	the angular acceleration of a body involved in a uniformly accelerated rotational motion whose angular velocity increases by 1 rad/s per one second
frequency	hertz	Hz	the frequency of a periodic phenomenon that has a period of one second
angular frequency		s^{-1}	the frequency of a rotational motion whose angular velocity corresponds to one revolution per second

Physical quantity	Name	Symbol	Definition
<i>Mechanic quantities</i>			
density		kg/m^3	the density of a uniform body having the volume of 1 m^3 and the mass of 1 kilogram
force	newton	N	the force that provides a mass of one kilogram with an acceleration of one metre per second
specific weight		N/m^3	the specific weight of a uniform body having the volume of 1 m^3 and the weight of one newton
pressure, compressive stress	pascal	Pa	the pressure (compressive stress) that results from a force of one newton acting uniformly over an area of one square metre
rigidity		N/m	the rigidity of a body which suffers an absolute strain of one metre under the action of an applied force of one newton
moment of force		$\text{N} \cdot \text{m}$	the moment of a force of one newton about a point at a distance of 1 metre from the line of action of the force
impulse of force		$\text{N} \cdot \text{s}$	the impulse of a force of one newton acting for one second
momentum		$\text{kg} \cdot \text{m/s}$	the momentum of a body of mass 1 kg involved in a translational motion and having a velocity of one metre per second
moment of momentum (angular momentum)		$\text{kg} \cdot \text{m}^2/\text{s}$	the moment of momentum (angular momentum) of a body with a moment of inertia of $1 \text{ kg} \cdot \text{m}^2$ and angular velocity of one radian per second
moment of inertia		$\text{kg} \cdot \text{m}^2$	the moment of inertia of a material point of mass one kilogram at a distance of one metre from the axis of inertia
surface tension		N/m	the surface tension arising when force 1 N is applied to an edge of liquid surface one metre long in the direction normal to the edge and tangent to the liquid surface

energy	joule	J	the energy equivalent to the work performed as the point of application of a force of one newton moves through one metre distance in the direction of the force
power	watt	W	the power resulting from the dissipation of one joule of energy in one second
dynamic viscosity		Pa·s	the dynamic viscosity of a medium involved in a streamline motion where the tangential force between two parallel layers of area 1 m^2 , 1 m apart, moving with a relative velocity 1 m/s , is one newton
kinematic viscosity		m^2/s	the kinematic viscosity at which the dynamic viscosity of a medium with density 1 kg/m^3 is 1 Pa·s
<i>Acoustic quantities</i>			
sound pressure	pascal	Pa	see pressure
acoustic impedance		Pa s/m^3	the acoustic impedance of a sound field where the rate of volume displacement of the vibrating surface is $1 \text{ m}^3/\text{s}$ at a sound pressure of 1 Pa
sound energy	joule	J	the sound energy equivalent to the work of 1 J
sound flux	watt	W	the sound flux equivalent to the power of 1 W
sound power	watt	W	the sound power equivalent to the power of 1 W
sound intensity		W/m^2	the sound intensity at which the sound flux through a 1 m^2 area normal to the direction of flow is equal to 1 watt
density of sound energy		J/m^3	the density of sound energy corresponding to 1 J energy per 1 m^3 of the sound field
<i>Thermal quantities</i>			
thermal energy	joule	J	see energy
specific heat, specific heat of combustion, specific heat of phase transition		J/kg	the specific thermal energy of a system (a process) where one joule of thermal energy is contained in (transferred to or from) 1 kilogram of matter

Physical quantity	Name	Symbol	Definition
heat capacity		J/K	the heat capacity of a system whose temperature increases by one kelvin upon the absorption of one joule of heat
specific heat capacity		J/(kg·K)	the specific heat capacity of a substance whose heat capacity is 1 J/K per 1 kg
heat flux		W	the heat flux equivalent to the power of 1 W
surface density of heat flux	watt	W/m ²	the surface density of a 1 W flux uniformly distributed over a 1 m ² area
entropy		J/K	the change of the entropy of a system to which n joules of heat is transferred in an isothermal process at a temperature of n K
thermal conductivity		W/(m·K)	the thermal conductivity of a substance in which a temperature gradient of 1 K/m is maintained under a surface density of heat flux of 1 W/m ² and steady state conditions
heat-exchange coefficient		W/(m ² ·K)	the coefficient of the exchange of heat corresponding to the surface density of heat flux of 1 W/m ² at a temperature difference of one kelvin
specific gas constant		J/(kg·K)	the specific gas constant of an ideal gas which, at a constant pressure, performs work of 1 J per 1 kg of the gas upon a temperature increase of 1 K
diffusion coefficient		m ² /s	the coefficient of diffusion at which 1 kg of a substance diffuses through a cross section of a 1 m ² area in 1 second at a concentration gradient of 1 kg/m ⁴
temperature coefficient of a physical quantity		K ⁻¹	the temperature coefficient of a relative change of a physical quantity at which a temperature variation of 1 K causes a variation of the quantity by one unit

electric charge	coulomb	C	the charge transported in one second by an electric current of one ampere
surface density of charge		C/m ²	the surface density of a uniform distribution of an electric charge of one coulomb over an area of 1 m ²
density of electric current		A/m ²	the density of a current of one ampere uniformly distributed over a conductor cross section of a 1 m ² area
electric potential difference	volt	V	the potential difference between two points on a conductor carrying a current of one ampere when the power dissipated is one watt
electric field strength		V/m	the strength of a uniform electric field with the potential difference between two points on a field line 1 m apart equal to one volt
electric capacitance	farad	F	the capacitance of a capacitor that acquires a charge of one coulomb when a potential difference of one volt is applied
electric resistance	ohm	Ω	the resistance between two points on a conductor through which a current of one ampere flows as a result of a potential difference of one volt applied between the points, the conductor not being a source of electromagnetic force
specific electric resistance		Ω · m	the specific resistance of a substance which being used as a conductor 1 m long of a 1 m ² cross section area has an electric resistance of one ohm
electric conductance	siemens	S	the conductance of an element that possesses a resistance of one ohm
specific electric conductance		S/m	the specific electric conductance of a substance which being used as a conductor 1 m long of a 1 m ² cross section area has a conductance of one siemens
absolute permittivity		F/m	the absolute permittivity of a medium where an electric displacement of 1 C/m ² arises as a result of an electric field of a 1 V/m strength

Physical quantity	Name	Symbol	Definition
electrochemical equivalent		kg/C	the electrochemical equivalent of a substance deposited in the amount of 1 kg upon the passage of one coulomb of electricity through the electrolyte
magnetic flux	weber	Wb	the flux that, linking a circuit of one turn, produces an electromotive force of one volt when the flux is reduced to zero at a uniform rate in one second
magnetic flux density (magnetic induction)	tesla	T	one weber of magnetic flux per metre squared
magnetomotive force	ampere	A	the magnetomotive force produced by an electric current of one ampere flowing round a closed path
magnetic field strength		A/m	the magnetic field strength in the centre of a long solenoid with a uniform winding in which a current of $1/n$ A (n is the number of coils per 1 metre) flows
inductance	henry	H	the inductance of a closed loop that gives rise to a magnetic flux of one weber for each ampere of current that flows
electromagnetic energy	joule	J	the amount of electromagnetic energy equivalent to one joule of mechanical energy
electric power	watt	W	the electric power equivalent to one watt of mechanical power
reactive power	var	var	the unit equivalent to the watt but used for the reactive power of alternating current; the reactive power developed in a circuit in which a current of one ampere flows under a voltage of one volt and $\sin \phi = 1$, where ϕ is the phase difference between the current and the voltage
apparent power	volt-ampere	VA	the apparent power developed in a circuit in which an alternating current of a 1 ampere effective ampere flows under an effective voltage of one volt

permeability	H/m	the permeability of a body in which an external magnetic field of 1 A/m induces a magnetic flux density of one tesla
<i>Luminous and radiant quantities</i>		
luminous flux	lm	the luminous flux emitted by a uniform point source, of intensity one candela, in a cone of solid angle one steradian
illumination	lx	the illumination of a surface produced by a luminous flux of one lumen per metre squared
luminance	cd/m ²	the luminance of a uniform luminous plane surface of a 1 m ² area in the direction normal to the surface at a luminous intensity of one candela
optical power of a lens	m ⁻¹	the optical power of a lens with the principal focal length of one metre
radiant energy	J	the radiant energy equivalent to one joule of mechanical energy
luminous energy	lm·s	the luminous energy corresponding to a flux of one lumen emitted or absorbed in one second
radiant flux (radiant power)	W	the radiant flux equivalent to a power of one watt

Ionizing radiation quantities

energy of ionizing radiation	joule	the ionizing radiation energy equivalent to one joule of mechanical energy
flux of ionizing radiation	watt	the flux of ionizing radiation energy equivalent to a power of one watt
dose of radiation (absorbed dose of radiation)	grey	the absorbed dose of radiation equal to one joule per kilogramme of material

TO THE READER

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We would also be pleased to receive any other suggestions you may wish to make.

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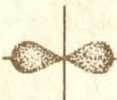
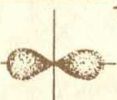
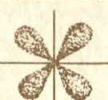

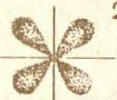

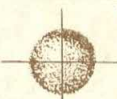
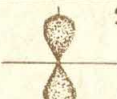
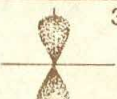

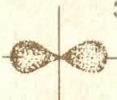
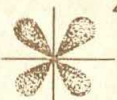

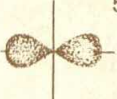
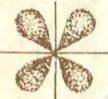
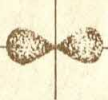
2 Pervy Rizhsky Pereulok

I-110, GSP, Moscow, 129820

USSR

DISTRIBUTION OF ELECTRONS IN ATOMS

	K L M N		K L M N O P		K L M N O P Q
1 H	1	36 Kr	2 8 18 8	71 Lu	2 8 18 32 9
2 He	2	37 Rb	2 8 18 8 1	72 Hf	2 8 18 32 10 2
3 Li	2 1	38 Sr	2 8 18 8 2	73 Ta	2 8 18 32 11 2
4 Be	2 2	39 Y	2 8 18 9 2	74 W	2 8 18 32 12 2
5 B	2 3	40 Zr	2 8 18 10 2	75 Re	2 8 18 32 13 2
6 C	2 4	41 Nb	2 8 18 12 1	76 Os	2 8 18 32 14 2
7 N	2 5	42 Mo	2 8 18 13 1	77 Ir	2 8 18 32 15 2
8 O	2 6	43 Tc	2 8 18 13 2	78 Pt	2 8 18 32 17 1
9 F	2 7	44 Ru	2 8 18 15 1	79 Au	2 8 18 32 18 1
10 Ne	2 8	45 Rh	2 8 18 16 1	80 Hg	2 8 18 32 18 2
11 Na	2 8 1	46 Pd	2 8 18 18 0	81 Tl	2 8 18 32 18 3
12 Mg	2 8 2	47 Ag	2 8 18 18 1	82 Pb	2 8 18 32 18 4
13 Al	2 8 3	48 Cd	2 8 18 18 2	83 Bi	2 8 18 32 18 5
14 Si	2 8 4	49 In	2 8 18 18 3	84 Po	2 8 18 32 18 6
15 P	2 8 5	50 Sn	2 8 18 18 4	85 At	2 8 18 32 18 7
16 S	2 8 6	51 Sb	2 8 18 18 5	86 Rn	2 8 18 32 18 8
17 Cl	2 8 7	52 Te	2 8 18 18 6	87 Fr	2 8 18 32 18 8 1
18 Ar	2 8 8	53 I	2 8 18 18 7	88 Ra	2 8 18 32 18 8 2
19 K	2 8 8 1	54 Xe	2 8 18 18 8	89 Ac	2 8 18 32 18 9 2
20 Ca	2 8 8 2	55 Cs	2 8 18 18 8 1	90 Th	2 8 18 32 18 10 2
21 Sc	2 8 9 2	56 Ba	2 8 18 18 8 2	91 Pa	2 8 18 32 20 9 2
22 Ti	2 8 10 2	57 La	2 8 18 18 9 2	92 U	2 8 18 32 21 9 2
23 V	2 8 11 2	58 Ce	2 8 18 20 8 2	93 Np	2 8 18 32 23 8 2
24 Cr	2 8 13 1	59 Pr	2 8 18 21 8 2	94 Pu	2 8 18 32 24 8 2
25 Mn	2 8 13 2	60 Nd	2 8 18 22 8 2	95 Am	2 8 18 32 25 8 2
26 Fe	2 8 14 2	61 Pm	2 8 18 23 8 2	96 Cm	2 8 18 32 25 9 2
27 Co	2 8 15 2	62 Sm	2 8 18 24 8 2	97 Bk	2 8 18 32 27 8 2
28 Ni	2 8 16 2	63 Eu	2 8 18 25 8 2	98 Cf	2 8 18 32 28 8 2
29 Cu	2 8 18 1	64 Gd	2 8 18 26 9 2	99 Es	2 8 18 32 29 8 2
30 Zn	2 8 18 2	65 Tb	2 8 18 27 8 2	100 Fm	2 8 18 32 30 8 2
31 Ga	2 8 18 3	66 Dy	2 8 18 28 8 2	101 Md	2 8 18 32 31 8 2
32 Ge	2 8 18 4	67 Ho	2 8 18 29 8 2	102 (No)	2 8 18 32 32 8 2
33 As	2 8 18 5	68 Er	2 8 18 30 8 2	103 (Lr)	2 8 18 32 32 9 2
34 Se	2 8 18 6	69 Tm	2 8 18 31 8 2	104 Ku	2 8 18 32 32 10 2
35 Br	2 8 18 7	70 Yb	2 8 18 32 8 2		

Energy Sublevels of a Given Level ($n^2 - \text{const}$)	I	II	III	IV
Respective Orbital Quantum Numbers L	0	1	2	3
Magnetic Quantum Numbers for a Given Energy Sublevel m_L	Characteristic Shapes of Electron Charge Clouds			
	s	p	d	f
-3				
-2				
-1				
0				
+1				
+2				
+3				
The Number of Different Orbitals for a Given Energy Sublevel $2L+1$	1	3	5	

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